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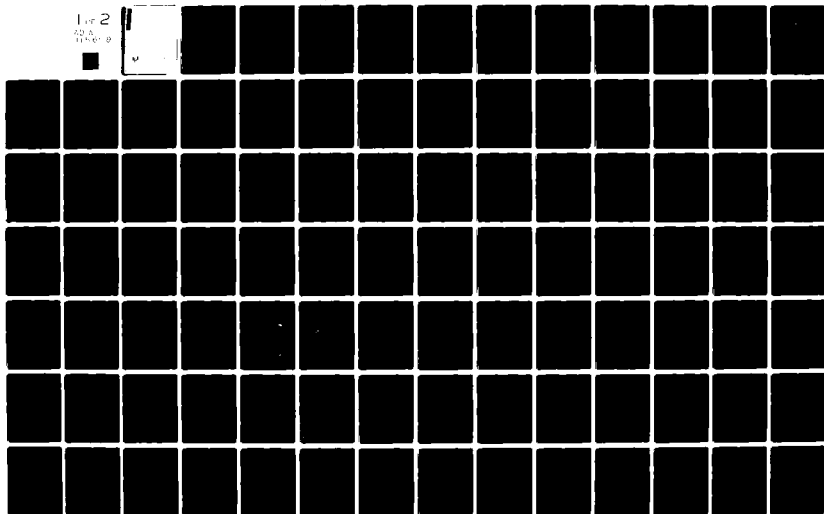
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Design, Operation and Performance of an Expendable Temperature and Velocity Profiler (XTVP)

by T.B. Sanford
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This report presents system design and implementation information for the Expendable Temperature and Velocity Profiler (XTVP). The topics include discussions of the probe, acquisition equipment, analysis soft- ware, probe calibration, launch procedures, and error analysis.		

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1. Introduction

The concept of measuring ocean currents from the motionally induced electric fields is an old one, having been first enunciated by Michael Faraday (1832). Numerous electric measurements have been made over submarine cables (Longuet-Higgins, 1949) and between electrodes towed behind a vessel (von Arx, 1950). More recently a profiling instrument called the Electro Magnetic Velocity Profiler (EMVP) has been developed by Sanford, Drever and Dunlap (1978). Experience with the EMVP suggested that a smaller, expendable version could be developed. This report describes this development and performance results.

The development of the expendable profiler began in 1976 under support from ONR Code 481 (now 422). A device was needed to sense voltages between two electrodes, effectively spaced 5 cm apart, to within 50×10^{-9} V rms over a 1 Hz bandwidth. The sensitivity results from the necessity to measure the expected signal to the equivalent of about 1 cm/s rms. To be operable from a ship under way, the device must not only be expendable but also able to transmit data to the vessel. For reasons of cost and convenience, body parts and wire spools from a T-7 XBT (Expendable Bathy-Thermograph, Sippican Corp., Marion, MA) were utilized, providing a suitable vehicle and the means for transmitting the data back to the vessel over the wire link.

Development activity proceeded into 1977 with the design of several electronics circuits and the performance of sea trials. The results were not encouraging; a persistent electronic instability arose within each probe.

During 1977, Code 500 of the Naval Oceanographic Research and Development Activity (NORDA) at Bay St. Louis, MS, took over program support. After the unsuccessful sea trials in 1977, efforts were concentrated on laboratory testing and theoretical evaluations to discover the cause of the electronic instability. Ultimately this problem was found to be due to feedback from the turns on the probe wire spool into the low-level electrode amplifiers.

By spring 1978, the instability had been isolated and new circuits designed to eliminate the problem. About two dozen probes were taken to sea on Oceanus Cruise 42 in April 1978. These probes were successful and revealed stable profile-to-profile repeatability.

In June 1978, a complement of over 50 probes was taken on Cruise 47 of the R.V. Oceanus as part of the Local Dynamics Experiment of the U.S./U.S.S.R. POLYMODE program. These probes, which we call XTVP's for Expendable Temperature and Velocity Profiler, were used simultaneously with our recoverable profiler (the Absolute Velocity Profiler, successor to the EMVP) and alone to study upper-ocean velocity features such as internal waves and fronts.

With the support of the Applied Physics Laboratory of the Johns Hopkins University, a series of performance tests was conducted in May 1978 at the U.S. Navy's AUTEC (Atlantic Underwater Test and Evaluation Center). A free-fall, acoustically tracked profiler was operated by Wenstrand (1979) as the standard against which the XTVP's were compared. These tests, reported by Sanford, Dunlap and Drever (1981), showed that the probes were accurate to within about 1 cm/s rms. The XTVP's do not measure the vertically averaged flow but reveal only the depth dependent part. Hence, the two profilers can only be compared with an unknown velocity offset. The 1 cm/s rms performance reflects the expected differences when the XTVP profile has been offset to match the acoustic profile's vertical average.

At the AUTEC trials, XTVP's manufactured by the Sippican Corporation according to a slightly different design were also tested. These did not perform quite as well as those built by APL-UW, and the changes incorporated were not included in subsequent units.

Several hundreds of Sippican-produced probes were deployed in experiments in the fall and winter of 1979-80. These probes performed well, with a failure rate of about 1 in 4.

During 1979, a new digital receiver was designed and built. This device determines the amplitudes and phases of the electric field and compass signals, from which the velocity estimates result. These quantities are derived from direct frequency evaluation of the FM signals, eliminating the analog stages (frequency to voltage and analog synchronous demodulation) of the original profile processor. The digital receiver was interfaced to an HP 9845T desk-top computer. Raw data were acquired in real time, but a processed profile requires too much computation to be produced in real time.

The recent emphasis of the program has been on our using the probes, assisting others in probe deployment and processing, and completion of a digital receiver, especially a means for internal digital storage.

To many readers it may seem unconscionable to expend such sophisticated probes. But when used to this maximum advantage, these devices provide invaluable results and save considerable personnel and operational costs. Operation of an equivalent recoverable instrument is very expensive in terms of capital equipment (support equipment, the profiler, spares, etc.), highly trained personnel (engineers, technicians, programmers) and ship time for launch, search and recovery. Clearly, there is some point at which the scientific and operational requirements argue strongly for the advantages of operational speed, real-time data presentation, logistical convenience and routine operation by minimally trained personnel.

II. Principles of Motional Induction

As seawater moves through the earth's magnetic field, electric fields, currents and magnetic fields arise. The physics is identical to that demonstrated as a wire connected to a voltmeter is moved between the poles of a magnet. The voltmeter registers an emf as the wire enters and exits the pole area. A similar experiment can be performed with the wire loop just in the presence of the geomagnetic field. If the loop were to change its area or be rotated, an emf would be induced. Note that the loop area projected onto the geomagnetic field must change. Motion of the loop and voltmeter in any rectilinear direction will not result in an induced emf. There seems to be a contradiction here in that we assert that velocity can be detected by the XTVP, but not in the above example. The resolution is that in the rigidly translating loop and voltmeter all circuit elements move together with no relative velocity. If the loop were elastic with a section moving away from the voltmeter, then an emf would arise proportional to the rate of change of magnetic flux through the loop area. If the voltmeter were also moving, then the emf may be proportional to the velocity of the loop section minus (or relative to) that of the voltmeter. The general point is that the emf is related to the motion of all circuit or loop elements. The same principle applies to the ocean; namely, the emf induced by the velocity at some depth will be relative to the velocities in the surrounding seawater. It is this fact that restricts the XTVP velocity measurements to be relative to an unknown, spatially averaged velocity. This restriction is indeed unfortunate, but there is one important consolation: the unknown is not depth dependent, so it represents only an offset having no vertical structure. In most, if not all, geophysical flows, the vertical scale of the motion is small compared with the horizontal length scale. This low aspect ratio leads to the assertion that the offset is not depth dependent. A more rigorous analysis of motional induction is presented by Sanford (1971), and Sanford et al. (1978) discuss induction using a discrete circuit analog.

In addition to the obvious problem of nanovolt measurement in the severe pressure and temperature environment of a profile, there are other special considerations. The fall rate of 4-5 m/s (8-10 knots) means that there will be an extremely large signal generated by this motion through the horizontal magnetic field. This voltage will be about 5 μ V. The extraction of voltage due to horizontal velocities (~ 50 nV) in the presence of a 40 dB larger one is difficult. A scheme is employed using the compass coil to cancel the bulk of the fall induced voltage. Another consideration is that electrodes have enormous (>1 mV) drifts and offsets and have broadband noise. To extract 50 nV signals, it is necessary to limit the bandwidth of the desired signal. This is achieved with a rapid probe rotation rate, which modulates the

ocean's emf and allows the separation of the induced signal from broad-band noise and the lower frequency drift of the electrodes. Finally, the transmission of the data to the vessel must be carefully executed to avoid feedback from the high-level output into the low-level input.

III. Method of Operation of the Expendable Profiler

The method of operation of the expendable temperature and velocity profiler has been developed based on our experience with a free-fall electromagnetic velocity profiler (EMVP; Sanford et al., 1978). The XTVP shown in Fig. 1 is made from standard expendable bathythermograph (XBT, Sippican Corp.) parts with the addition of a 29.5 cm center section of active electronics. As the probe falls and spins through the water column, it modulates the motionally induced electric field at its spin frequency. These weak signals are amplified and converted to an FM signal that is transmitted over a pair of #39 wires to the ship.

The signal $\Delta\phi$ from a falling, rotating electrode line pointing in the direction θ , measured clockwise from geomagnetic north, in the presence of the motionally induced electric currents in the sea is

$$\Delta\phi = F_z L(u - \bar{u})(1 + C_1) \cos\theta - [F_z L(v - \bar{v})(1 + C_1) - F_H L W(1 + C_2)] \sin\theta, \quad (1)$$

where

- F_H and F_z = horizontal and vertical components of the geomagnetic field, taken here as $1/4$ and $-1/2 \times 10^{-4}$ tesla,
- L = length of electrode line = 5×10^{-2} m,
- $u - \bar{u}$ and $v - \bar{v}$ = east and north horizontal velocity components minus a vertically-averaged contribution,
- C_1 and C_2 = scale factors depending on the shape of the probe ≈ 1 and 0 ,
- W = vertical component of velocity (negative value for falling probe) ≈ 4 m/s.

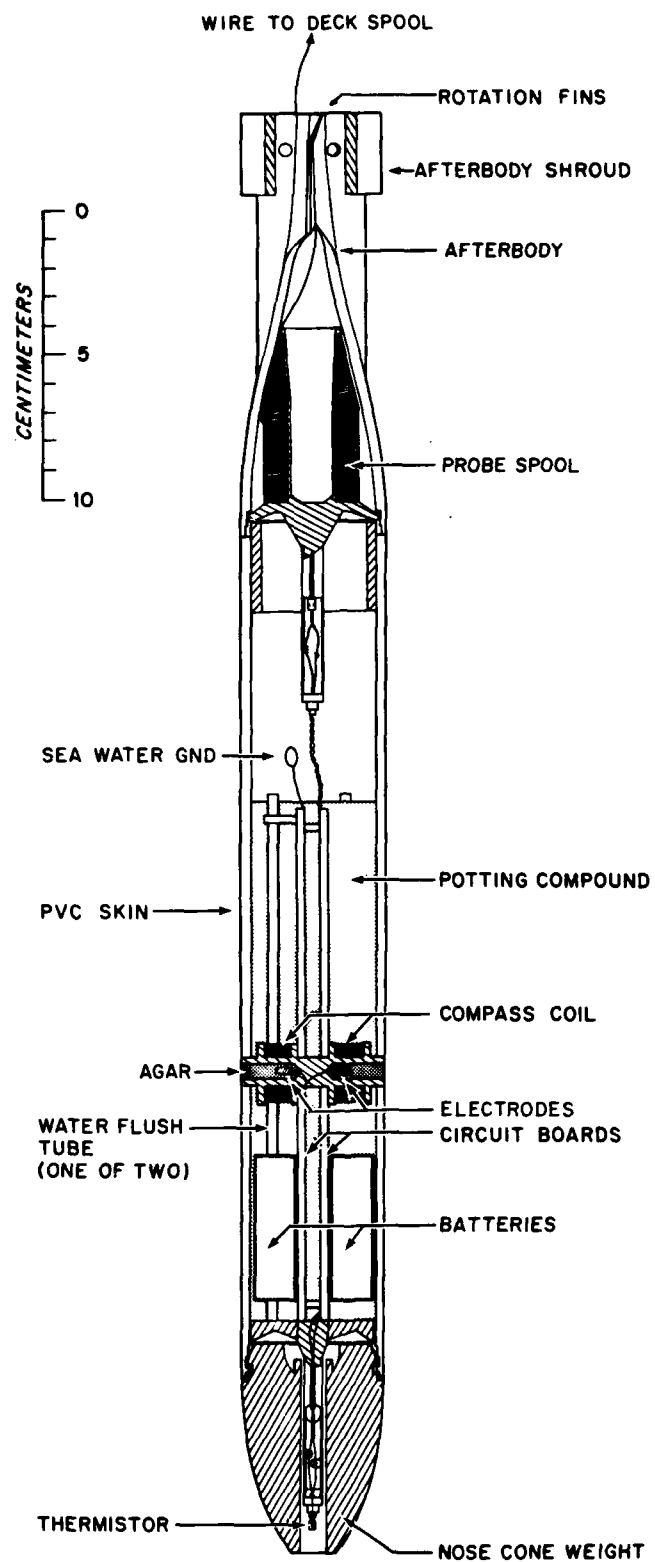


Figure 1. Expendable Temperature and Velocity Profiler (XTVP)

The magnitudes of the terms are found for $u-\bar{u}$ and $v-\bar{v} = 1$ cm/s using

$$F_Z L(u-\bar{u})(1+C_1) = F_Z L(v-\bar{v})(1+C_1) = -50 \times 10^{-9} \text{ V} , \quad (2)$$

and

$$F_H L W (1+C_2) = 5 \times 10^{-6} \text{ V} . \quad (3)$$

The very low signal levels place stringent requirements on the expendable electronics. The desired signal of $0.05 \mu\text{V}$ represents 1.0% of the $5 \mu\text{V}$ signal induced by fall speed. To resolve the desired signal to an uncertainty of 1 cm/s requires that the gain of the amplifiers be stable within 1.0%, that the phase of the signal relative to the electrode line orientation be determined to 0.6° , and that the fall speed be known to about 1.0%.

The 0.6° is a specification that is very hard to meet in an expendable probe. The phase error tolerance can be improved by mixing a portion of the coil signal with the electric field. The amplitude of the coil signal is given by $F_H \omega n A$, where ω is the rotation rate and nA is the effective area times the number of turns. Consequently, the electric field signal plus the coil contribution would be

$$\text{in-phase} = -F_Z L(v-\bar{v})(1+C_1) = F_H L W (1+C_2) - F_H \omega n A C_3 , \quad (4)$$

where C_3 is the fraction of the coil signal added. The value of C_3 is chosen such that for average fall rates and rotation frequencies (W and ω) the two terms nearly cancel. That is, we find that $\omega = 50 \text{ s}^{-1}$ and $nA = 10^3 \text{ cm}^2$, hence

$$C_3 = \frac{L \bar{W} (1+C_2)}{\omega n A} \sim \frac{1}{25} . \quad (5)$$

The principal benefit of this procedure is to reduce by about 90% the magnitude of the in-phase signal, making the in-phase and quadrature signals of comparable strength. In this case, phase shift uncertainties in the probe and deck equipment can be as large as $\pm 6^\circ$ without degrading the ± 1 cm/s performance goal.

The low-noise preamplifiers used in the probes have a noise voltage of about 10×10^{-9} V/ $\sqrt{\text{Hz}}$ in the 5 Hz to 1000 Hz band referred to input. This noise level corresponds to an $\sim 1/4$ cm/s rms uncertainty in velocity.

The discussion of the hardware is divided into topics related to the probe construction and electronics and the receivers, both analog and digital versions.

A. PROBE

1. Package and Construction

The mechanical design of the probe is shown in Fig. 1. The probe is 52 cm long, 5 cm in diameter, and weighs in air approximately 1470 grams. In seawater the probe weighs about 800 grams. The three main parts of the probe are the afterbody, electronics section and nose weight.

The afterbody contains a spool of approximately 900 m of two-conductor, #39 wire used to send data to the surface. A shroud in the form of a right cylindrical shell has been mounted on the afterbody to stabilize the fall of the probe. The fins of the afterbody make the probe rotate at about 450 rpm.

The electronics section contains two printed-circuit boards, batteries, electrodes, compass coil and thermistor flushing tubes, all potted inside a thin-walled PVC tube. The potting is a soft compound which allows the components to be at pressure equilibrium with the surrounding seawater. The electric field sensor is made up of two silver-silver chloride electrodes in tubes filled with agar to form a salt bridge for making electrical connection to the seawater at the outer skin of the probe. The compass coil is a coil of wire wound coaxially over the electrode tubes.

The nose weight is made of zinc, weighs about 500 grams in seawater and supplies the main driving force causing the probe to fall. A thermistor is mounted in the hole in the center of the nose weight. The thermistor is flushed by water passing through the nose cone and then through the flushing tubes which are potted in the electronics section.

2. Electronics

The electronics are made up of sensor preamplifiers, three voltage-to-frequency converters (V/F), a battery pack, voltage reference, mixer and line driver. Figure 2 is a block diagram of the probe electronics.

The electric field, as sensed by the electrodes, is amplified by a low noise preamplifier. The signal generated by the rotation of the compass coil in the earth's magnetic field is also amplified. The compass coil and the electrodes have been wired so that the output of the compass amplifier will be 180° out of phase with the part of the electric field amplifier output that is due to the fall rate term, $F_{H,LW}(1+C_2)$, of Eq. (1). As described in Eq. (4), a small amount of the compass coil amplifier signal is added to the electric field amplifier signal to cancel most of the fall rate term. The output of the electric field post-amplifier is ac coupled into a V/F converter. The reference voltage is used to offset the V/F to operate at the center frequency of its designated channel. The output of the V/F is divided by two to eliminate the even harmonics. The signal is then filtered to reduce the third harmonic and to give a 10 dB boost to the higher-frequency portion of the channel over the lower-frequency end. The compass signal is also ac coupled into a V/F, and the output of the V/F is divided by two to remove the even harmonics.

The thermistor is used with the reference voltage to modulate a third V/F. The output of the temperature V/F is divided by two to remove the even harmonics. The signal is then filtered to reduce the odd harmonics.

The three FM channels are amplified to compensate for the different signal attenuation on each channel (caused by the wire link to the ship-board processing system), mixed and impressed on the wire link. Design signal levels and the actual signal levels out of a wire link for a couple of drops are shown in Fig. 3. There are curves showing the signal levels at the start and end of a drop. The attenuation of signal on the wire can be as much as 120 dB at 5 kHz with all the wire in the water. Figure 4 shows the frequency spectra of signals out of the digital receiver preamplifier at three different times for drop #67. The broadband energy centered at 2500 Hz in the top spectrum is caused by the electric field amplifier in the probe being open-circuited while in air in the deck launcher. The figure shows that even when the signals are greatly affected by the wire links they still stand out well above the noise.

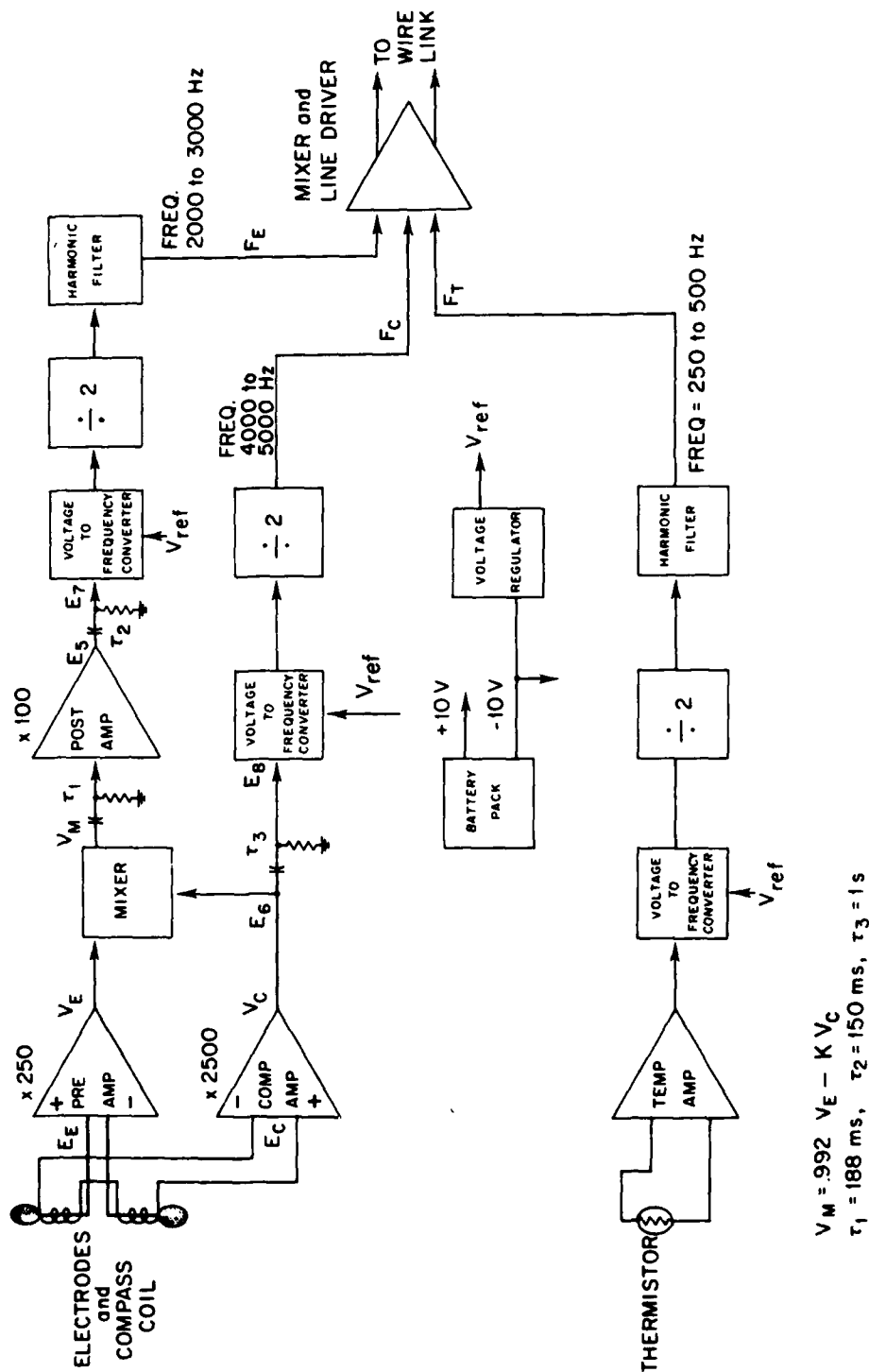


Figure 2. Diagram of probe electronics.

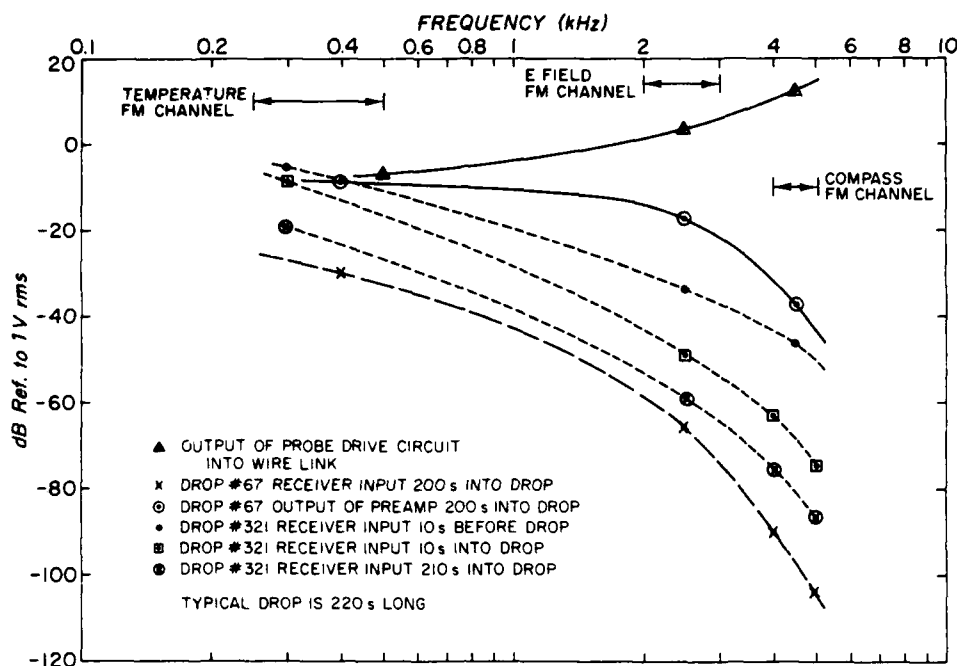


Figure 3. Typical signal spectra at probe, receiver input and after preamplifier at various times into a drop.

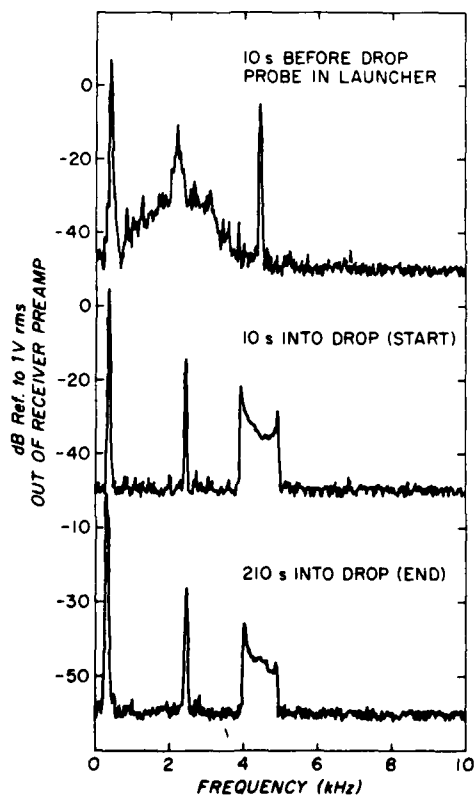


Figure 4.

Signal spectra 10 seconds before and after probe launch, and near the end of a drop.

B. ANALOG RECEIVING SYSTEM

The analog receiving system, Fig. 5, consists of the XTVP receiver, two custom-designed plug-in units for a Tektronix TM 500 module, and standard laboratory instrumentation.

The three channels of FM data are transmitted to the ship by way of the expendable wire link. The signals are transformer coupled, amplified and filtered into the three separate frequency bands. These three FM signals are recorded on an HP 3960 tape recorder so the data can be replayed after the drop. The period of the temperature frequency is measured in a counter and converted to a voltage V_T which can be displayed on the XY plotter. The electric field and compass frequencies are converted to voltages, V_E and V_C , respectively, that are a linear representation of the voltages sensed by the probe.

The compass voltage V_C is used as a reference signal for the two-phase, lock-in amplifier (PAR, Inc., Model 129). The lock-in amplifier synchronously demodulates the electric field voltage into in-phase (north-south) and quadrature (east-west) components with respect to the compass signal. These signals are recorded in the two-pen XYY recorder as a function of time (depth) in real time as the probe is falling. Thus, the velocity data are available for immediate examination and analysis in analog form.

The processing system also measures and plots the in-phase and quadrature components of the compass signal and the period of the compass signal.

The velocity profiles produced by the analog system contain errors and lack corrections for known systematic effects. To compute corrected profiles, it is necessary to digitize the analog plots. To accomplish this we have used an HP 9874A digitizer and an HP 9845 desk-top computer. The analog receiver has now been replaced by a digital version; the analog receiver now serves as a backup to the digital receiver and provides real-time information.

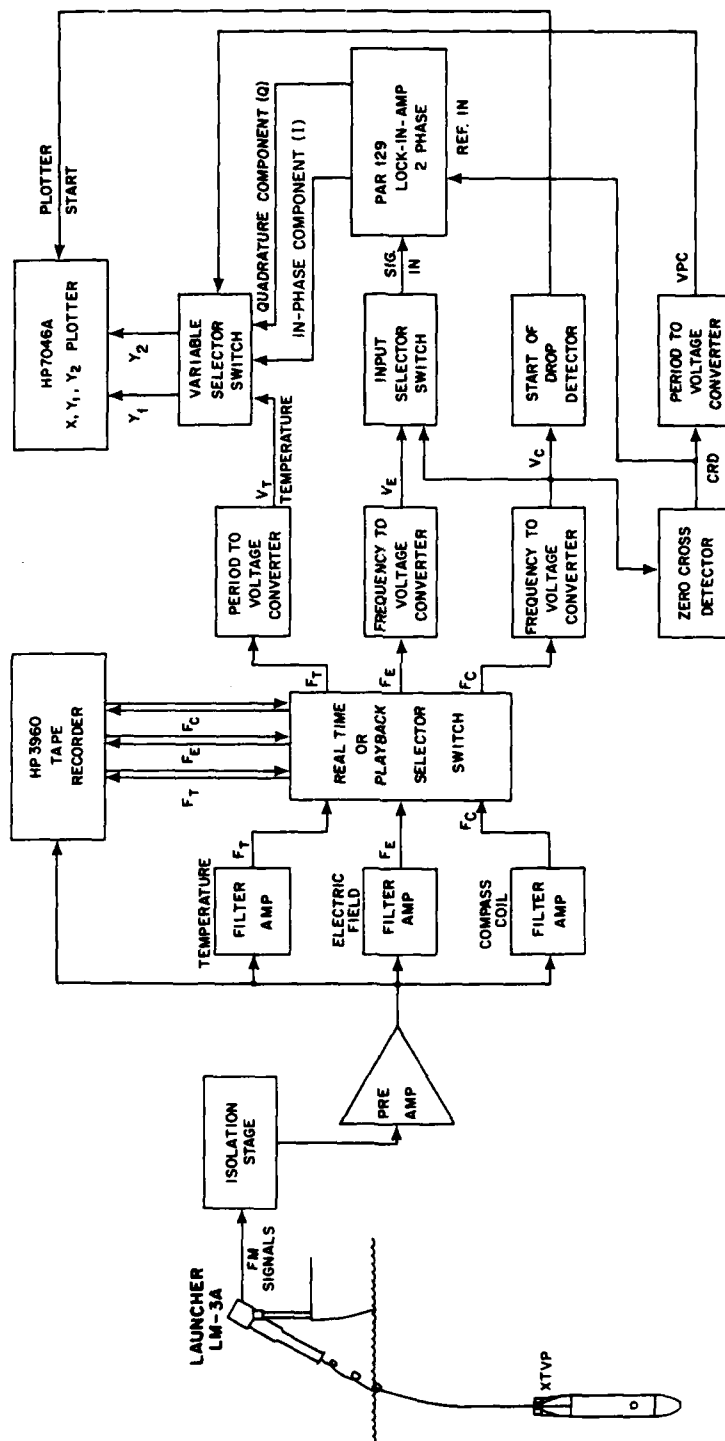


Figure 5. Analog or digital-backup XTVP shipboard processing system.

C. DIGITAL RECEIVER

The XTVP digital receiver is a one-box unit that takes the composite FM signals from the wire link and processes them into digital data that are recorded on an internal magnetic cartridge tape recorder. In this way, the receiver is capable of being used without an on-line computer. With an X, Y_1, Y_2 plotter, as shown in Fig. 6, the receiver can be used to obtain real-time plots of u and v with X equal to the product of time and a constant fall rate similar to those produced by the analog receiver. It is recommended that a backup magnetic tape recording be made of the FM signals. The data must be further processed by a computer to get completely processed profiles.

1. Preamplifier, Filters and Carrier Detector

The preamplifier and filters take the signal from the output of the wire link, amplify, and separate the FM signal into the three channels. The signals from the wire link are coupled into the launcher and fed to the input of the receiver by a shielded, four-wire cable. At the input to the receiver, the signal is passed through an isolation transformer followed by the preamp which has frequency-dependent gain. The compass channel has a gain of approximately 40 dB. The electric field channel is boosted approximately 25 dB, and the temperature channel has a gain of approximately 10 dB. The effect of the nonuniform gain appears in Fig. 4 as the difference between the two curves showing drop #67 signal levels into the receiver and out of the preamp. The signal then goes through three bandpass filters that separate and further amplify the signals. The outputs of the filters are recorded on a magnetic tape recorder and applied to the inputs of the carrier detectors. When the carrier voltage of each channel goes above a preset value, the FM signal will be gated into the phase lock loops. The carrier detector circuit serves to keep the phase lock loop squelched until a carrier is present. The carrier detector generates 3 bits of the status data word which is used by the processing computer to determine that all carriers are present during the drop.

2. Phase Lock Loops

The phase lock loops perform the three functions of frequency multiplication, frequency-to-voltage conversion and signal-to-noise improvement at low carrier levels.

The most important function of the phase lock loops (PLL) is to multiply the carrier frequency such that a zero crossing counter will have sufficient resolution for making the velocity determinations. The electric field carrier frequency has a transfer function from the input of the electrodes of the probe to the PLL input of 2.5 Hz per 0.1 μ V peak to peak. An ocean flow having a horizontal speed of 1 cm/s in a

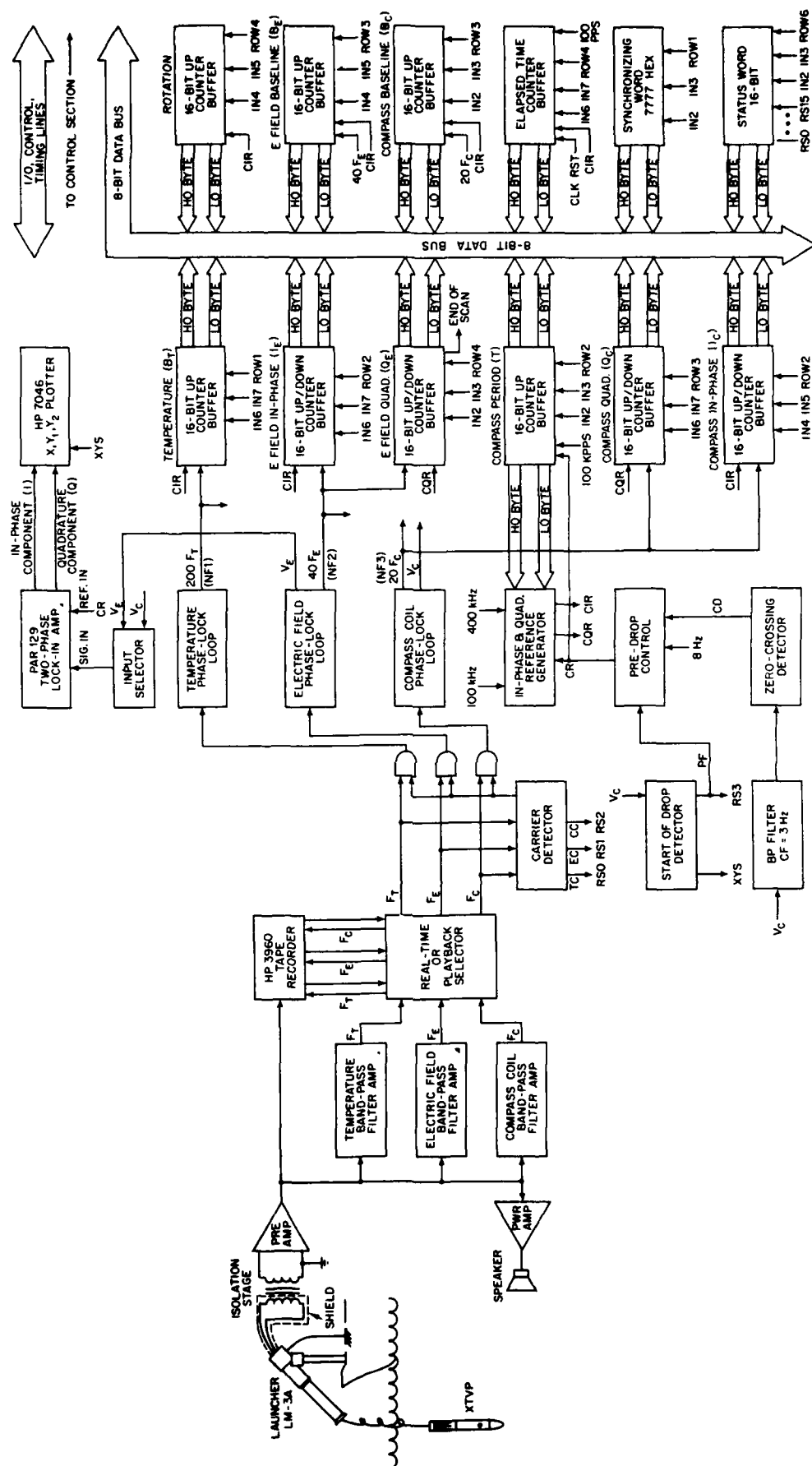


Figure 6. Processing section of XTVP digital receiver (control and I/O sections shown in Fig. 8).

vertical geomagnetic field of $1/2 \times 10^{-4}$ tesla will induce a signal of 0.1 μV peak to peak at the probe electrodes. The electric field carrier frequency is multiplied by 40, increasing the transfer function to 100 Hz per 0.1 μV peak to peak. The counters are used in an up/down count mode over one period of probe rotation. Because the up/down counter accumulates over one period, and the modulation of the carrier is a sine wave at the period of rotation, it can be shown that

$$TC = \frac{2F_p N}{\pi} P, \quad (6)$$

where

TC = total counts in up/down counter,
 F_p = deviation of carrier frequency per μV ,
 P = period of rotation in seconds,
 N = multiplication factor of PLL.

For $P = 0.125$ s, $F_p = 25$ Hz/ μV and $N = 40$, $TC = 125$ counts/ $\mu\text{V} \approx 12.5$ counts/cm/s.

The second function that the PLL's perform is frequency-to-voltage (analog) conversion of the electric field and compass FM signals. The compass analog voltage signal is used by the reference generator to produce reference signals for the phase-sensitive demodulation of the FM signals. The electric field and compass analog signals can also be used with a two-phase lock-in amplifier as was done in the original analog receiver described previously.

A third function of the PLL is to achieve an improvement in signal-to-noise ratio at small carrier-to-noise ratios. The output signal-to-noise ratio of an FM signal is (Schwartz, 1966)

$$\frac{S_o}{N_o} = 3\beta^2 \frac{S_c}{N_c}, \quad (7)$$

where

$\frac{S_c}{N_c} \equiv$ FM carrier-to-noise ratio (must be greater than 10),

$\beta \equiv \frac{\Delta f}{f_m} =$ modulation index,

$f_m \equiv$ frequency of the modulation in radians/s,

$\Delta f \equiv$ deviation of the carrier frequency from zero modulation frequency of the carrier.

For $\Delta f = 500$ Hz, $f_m = 8$ Hz and $S_c/N_c = 10$, $S_o/N_o = 39,000$ or 46 dB.

Below the $S_C/N_C = 10$ threshold, Eq. (7) is not valid, and S_O/N_O declines about 30 dB by the point where $S_C/N_C = 1$. Schwartz (1966) shows that a PLL can be used to move the threshold down to about 0 dB giving a threshold improvement of 10 dB.

3. Reference Generator and Up/Down Counter

The reference generator and the up/down counters perform the function of phase-sensitive demodulation of the FM signals into two orthogonal components. The reference generator generates two reference signals, CQR and CIR, with the former lagging the latter by 90°. These signals are used to control the up and down counting times of the up/down counters. Figure 7 shows the important signals that are used to generate the reference signals for controlling the up/down counters. V_C is the ac coupled demodulated analog signal out of the compass PLL. The signal CR is generated by detecting the zero crossings of V_C . The period of CR is measured by a digital counter for every rotation of the probe with a resolution of 10 μ s. The period measurement is stored on the tape recorder and in a temporary buffer. The data in this temporary buffer are used to preset a down counter which counts at a rate four times faster than the period up counter. This down count is repeated to generate the signal S1, which is a series of pulses that roughly divides the time period into four equal parts. The S1 signal is used to generate the S2 signal. S2 is generated by a one-stage flip-flop that is reset at t_0 and t_4 and stepped at t_1 , t_2 and t_3 . The positive-going edge of S2 is used to clock the state of CR into a 1 bit data register. The output of the data register is the Compass Quadrature Reference signal (CQR). The Compass In-Phase Reference (CIR) is generated by clocking a one into a data register at t_0 to t_4 and a zero in at t_2 . There are small errors in the generation of CQR and CIR, which are corrected when the data are processed in the computer. CIR is used rather than CR because if there is any baseline wandering of V_C it will appear as noise in the timing of the negative-going edge of CR. But since the time of the negative-going edge of CR is not measured, a correction cannot be implemented.

The four up/down counters shown in Fig. 6 are controlled by CQR and CIR. These counters up/down count the PLL frequencies, NF_2 and NF_3 . At the end of a count period, the counters have measured the in-phase and quadrature components of the electric field and compass signals. The two components of the compass signal are used to correct for the phase shift error caused by the receiver between CQR and the FM modulated signal from which V_C is derived. The compass components are also used to eliminate the fall velocity component. The up/down counters average

the baseline carrier frequencies of the FM signals. These are counters that just count up, making a measurement of the baseline carrier frequencies of electric field, compass coil and temperature signals. There is also a counter that measures elapsed time to the nearest 10 ms.

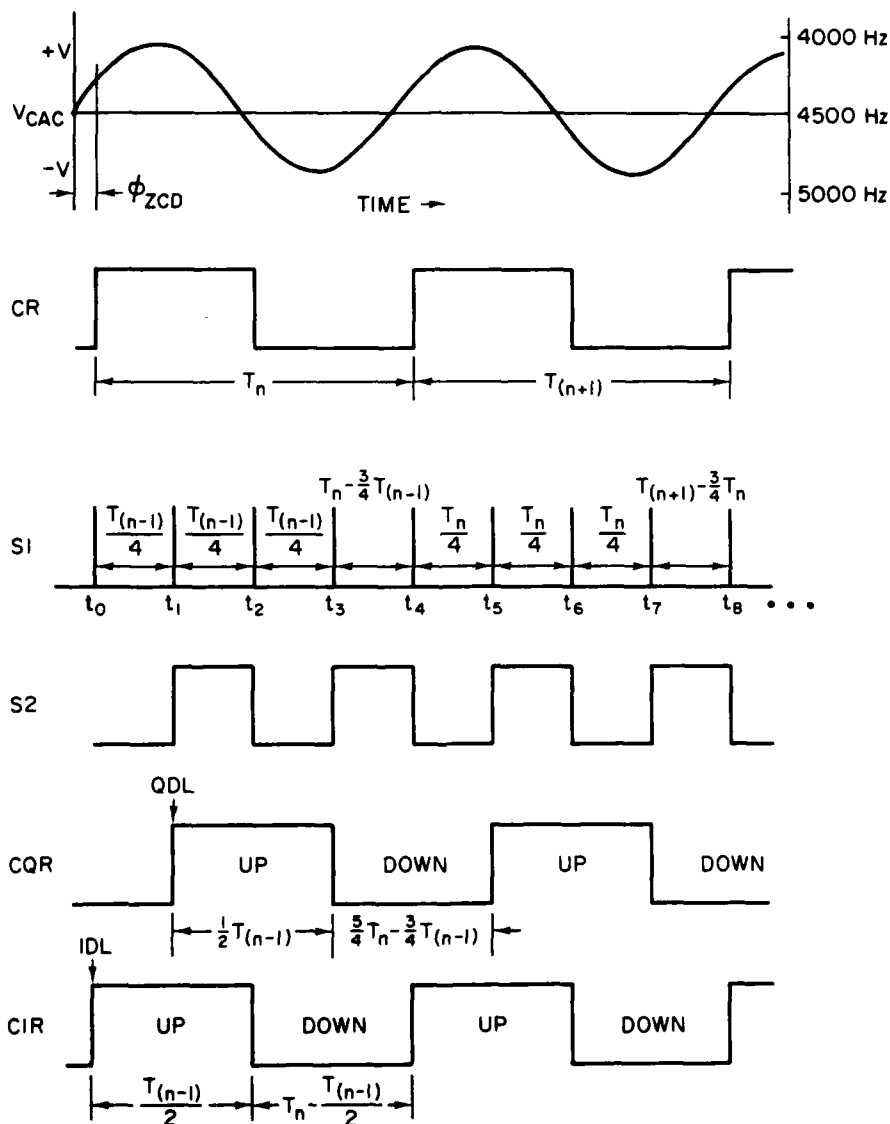


Figure 7. Timing diagram for in-phase and quad-phase counters.

4. Pre-Drop and Start of Drop Controls

The start of a drop is detected by sensing when the compass analog signal V_C goes above a preset threshold. Going above the threshold sets a flag called PF (probe falling) and, as long as the threshold is reached at least once every 600 ms, the flag will stay true.

The threshold is set so that when a probe starts falling and rotating the PF flag will turn on within 1 s. The threshold setting is dependent on the earth's horizontal magnetic field. The threshold can be increased near the magnetic equator to reduce false triggers. At high latitudes the threshold must be reduced. Note that when the horizontal magnetic field is nearly zero the system cannot develop an accurate CD signal and thus velocity information is compromised.

The PF flag is used by the receiver to switch CR between an 8-Hz square wave generated by the time base and CD. V_C is used to generate CD by passing it through the zero-crossing detector. The 8 Hz square wave is used as a default signal by the receiver to collect data before and after a drop. Without it there would be no timing signals for the counters.

5. Controller

The controller shown in Fig. 8 regulates the collection and processing of digital data in the receiver. The heart of the controller is an RCA 1802 microprocessor with 6K ($K=1024$) bytes (8 bits) of EPROM (erasable, programmable read-only memory) and 16K bytes of RAM (read and write memory). Data are collected by the controller, stored on internal magnetic tape and sent to the HP 9845 computer. The flow of data is controlled by a seven-level priority code for interrupts and DMA (direct memory access) transfers.

The receiver's operator enters data and commands through a 16-pad numeric keyboard, a 20-digit alphanumeric display and control switches on the front panel. The operator is able to enter into the receiver the data to be recorded on the magnetic tape along with the profile data collected during an actual drop. The data recorded and the storage format will be discussed later in the tape recorder section.

The controller also has the capability of performing a small amount of data processing to provide a quick look at the profiles in real time on an external XYZ plotter. The counter values from a single rotation are normalized by the rotation period and averaged over a number of rotations. These processed data are sent to the three, digital to analog converters.

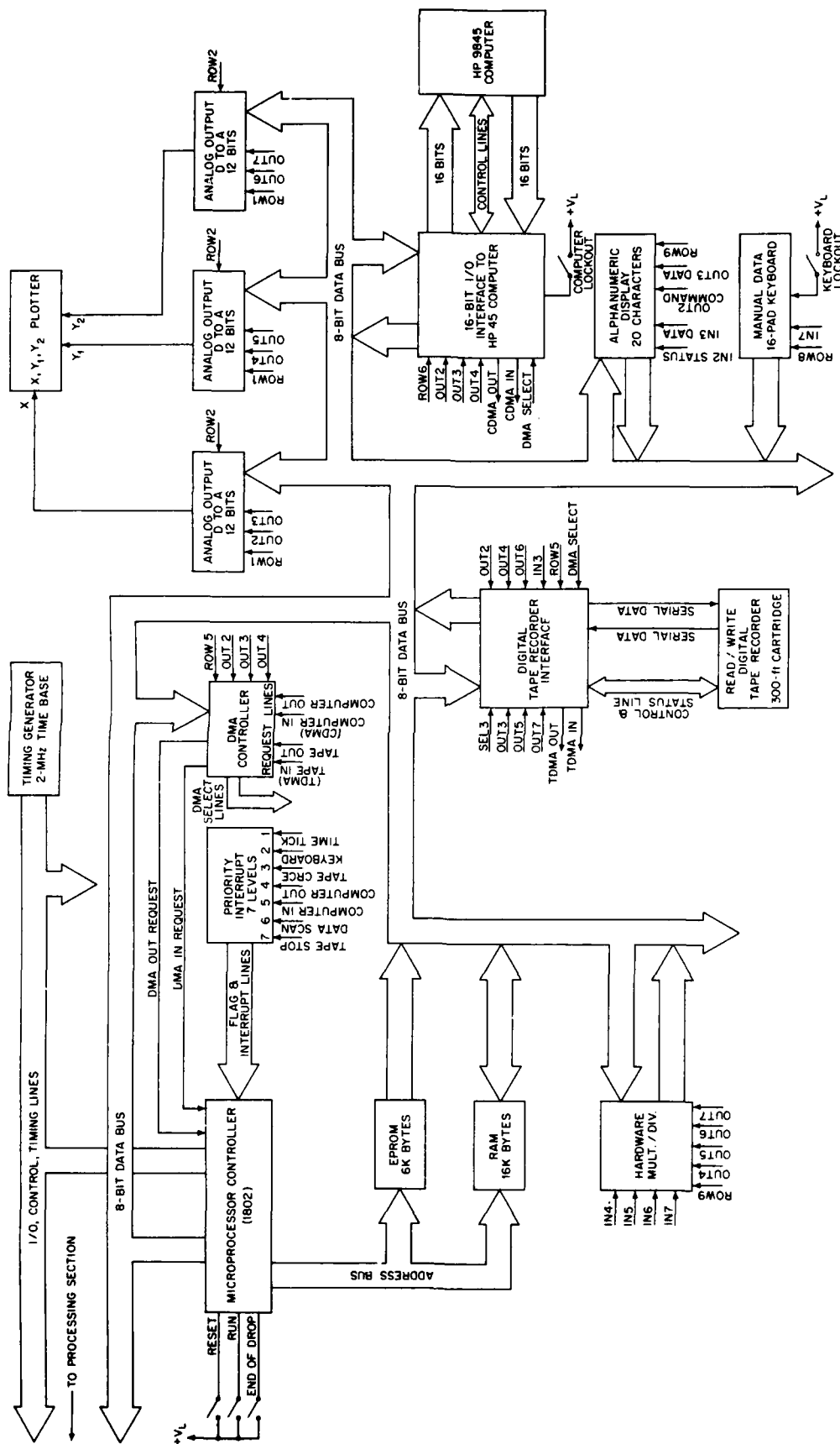


Figure 8. Control and I/O sections of XTVP digital receiver.

Data from the signal processing section buffers are collected once every rotation of the probe and stored in RAM until a 2K byte buffer is filled. The controller then sends the 2K data buffer to the tape recorder and HP 9845. Besides storing data, the controller can also find the digital data for a particular drop on the digital tape recorder and play it back for quick-look processing or pass it on to the HP 9845.

6. Digital Tape Recorder

The tape recorder is Digital Electronic's Model 3447 cartridge magnetic tape drive with four tracks and erase, write and read heads. We use 3M DC300A 1/4-inch tape cartridges with a storage capacity of approximately 10 million bytes of unformatted data. Data are recorded serially at 6400 bits per inch.

The data capacity is much greater than is needed by the receiver, but it was cost effective to use a design shared with another program. One cartridge can store more than 50 drops, but because of the high probe cost relative to tape cost it is recommended that not more than 10 drops be put on a cartridge.

The tape drive reads immediately after writing and performs a CRC (cycle redundancy check) on the data read. In the event of an error, the data block is recorded again (without backspacing and erasing the first). The controller will try three times to write the data block, and then move on to record the next block of data.

Data are recorded in 2K-byte-long records. There are only three types of records: data records, end-of-file records and end-of-information records. The end-of-information record indicates where recording can begin without writing over previous data; it is always added to the tape at the completion of a drop. Because the amount of data storage is not a problem, all records have 128 byte headers. The header is made up of words that are 2 bytes each (16 bits). Table 1 is a list of the words and their position in the header.

The preamble is used by the tape recorder electronics to find a record during a tape read. When the recorder is searching for data, it looks for at least 39 zeros followed by a one before it will put its DAD (data detected) line true.

The controller will write an end-of-file record and an end-of-information (EOI) record at the end of each drop when the operator sets the end-of-drop switch on the front panel. When a new drop is to be recorded on tape, the controller looks for the EOI record and positions the tape write head in the inter-record gap before the EOI record. At the start of writing the new drop, the EOI record will be erased.

Table 1.

<u>Word #</u>	<u>Name</u>	<u>Data (HEX)</u>
1	Preamble	0000
2	Preamble	0000
3	Preamble	0001
4	Keyword (record type)	
	Data record	AAAA
	End-of-file record	AAAB
	End-of-information record	AAAC
5	Record #	
6	Number of times the record has been recorded on tape	
7	Version # of receiver program	
8	Number of data words per scan	
9	Tape # (cartridge #)	
10	Track #	
11	Cruise #	
12	Drop #	
13	Version # of drop	
14	Number of files on tape, including this drop	
15	Real time year	
16	Real time day of year	
17	Real time hours (24)	
18	Real time minutes	
19	Real time seconds	
20	Number of previous scans in this file	
21	Number of previous scans in this record	
22-64	These are spares that are filled with all F's.	

Each record has one record header and 64 scans of data. One scan of data contains all the data collected during one rotation of the probe. The makeup of the scan is given in Table 2.

Table 2.

<u>Channel #</u>	<u>Name</u>	<u>No. of Bytes</u>
1	Sync. word (7777HEX)	2
2	Status	2
	Bit # (true state = 1)	
	0 temperature carrier present	
	1 E field carrier present	
	2 Compass carrier present	
	3 Probe falling (PF)	
	4 Compass channel F3	
	5 8 Hz default OFF	
	6 Manual XY start	
	7 Real time mode	
	8 CTLO (HP 9845 control line 0)	
	9 CTLI (HP 9845 control line 1)	
	10 Spare	
	11 Spare	
	12 Spare	
	13 Spare	
	14 Spare	
	15 End of drop	
3	Temperature baseline (B_T)	2
4	Period of rotation (T)	2
5	Compass in-phase (I_C)	2
6	E field in-phase (I_E)	2
7	Compass baseline (B_C)	2
8	E field baseline (B_E)	2
9	Compass quadrature (Q_C)	2
10	E field quadrature (Q_E)	2
11	Rotation counter	2
12	Elapsed time counter	2
13	Real time hours (24/day)	2
14	Real time minutes	2
15	Real time seconds	<u>2</u>
	Total	30

For a rotation rate of 8 Hz, it takes about 8 seconds to fill the 2K byte buffer of data.

7. Computer Interface

The HP 9845T computer is connected to the receiver by a 16 bit parallel I/O interface. The computer can send control words to the receiver to initialize a transfer of data. The receiver is designed to allow the HP 9845 to read and write anywhere in the RAM memory space of the receiver. The HP 9845 can also read from the EPROM memory space to check the EPROM in case of a problem that is caused by the receiver program. Data are transferred through the interface by DMA. The maximum rate of data transfer is limited by the receiver to about 64K bytes per second, not including the transfer setup time of the 9845. It takes about 32 ms plus setup time to transfer a 2K byte block of data.

During a probe drop, the 9845 can be locked out from writing into the memory of the receiver. With the computer lock-out switch on, only the data blocks will be transmitted to the 9845.

8. Analog and FM Outputs

The receiver has analog and FM outputs that are used for a quick look and for backup data storage. There are two means for getting a quick look at the analog profile. The analog voltages of electric field and compass coil are available on BNC connectors on the front panel. These signals can be fed into a two-phase lock-in amplifier that will demodulate the electric field into two components using the compass coil voltage as a reference signal. The components are displayed on an X, Y_1, Y_2 plotter as a function of time. Also, as mentioned in the controller section, there are D to A outputs on the front panel that can be used to drive an X, Y_1, Y_2 plotter.

The receiver has available on the front panel FM carriers for temperature, electric field and compass to be recorded on an HP 3960 or similar instrumentation recorder for backup. The FM signals can be played back through the front panel connectors to reprocess a drop any time it is needed.

D. SOFTWARE

HP 9845T BASIC language programs are described here. DXGET is for acquisition, DXPRO for processing, SPLOT for series plotting, CROSS for cross-correlation, structure-function, and coherence. Listings and sample runs are found in Appendix A.

1. Acquisition--DXGET

DXGET accepts a user-specified number of data scans (one repetition of all variables) from the digital receiver. The computer's real-time clock is sampled just before starting the single DMA ENTER statement into the integer data array, Din(*). Because ENTER must run to completion, the 8 Hz default in the receiver must be on. The program was kept very simple so as not to risk data loss.

After the data are ENTER'd, the user enters comments and the file name. The data are then written to mass-storage, either floppy disc or tape cartridge.

2. XTVP Signal and Data Processing Description

The XTVP probe and digital receiver transfer functions are described to provide a basis for the application of a signal model. Careful attention to gains, phases and timing is required to determine oceanic water velocity profiles accurately.

The probe input stages shown in Fig. 2 can be described with three transfer functions for electric field, fall speed correction and compass coil:

$$G_{EF2} = \frac{E_7}{E_E},$$

$$G_{COR2} = \frac{E_7}{E_C}, \quad (8)$$

$$G_{CC2} = \frac{E_8}{E_C}.$$

Estimated gains and phases are functions of frequency and typically are represented as phasors, $G = G_a \angle G_p$, where G_a is the magnitude of G and G_p is the phase of G .

Voltage to frequency (V/F) converter factors in the probe are

$$G_{EFVF} = \frac{F_E}{E_7} \quad (\text{Hz/V}) , \quad (9)$$

$$G_{CCVF} = \frac{F_C}{E_8} \quad (\text{Hz/V}) .$$

Solving for the probe inputs as a function of outputs yields

$$E_E = \frac{F_E}{G_{EFVF} G_{EF2}} - E_C \frac{G_{COR2}}{G_{EF2}} , \quad (10)$$

$$E_C = \frac{F_C}{G_{CCVF} G_{CC2}} ,$$

where all quantities are complex because both amplitude and phase are needed.

Gain amplitudes for each probe are measured during manufacture; phases are estimated from a transfer function analysis using nominal component values. The analog gains measured at 7 Hz are

$$G_{EF} = E_7/E_E ,$$

$$G_{COR} = E_7/E_C , \quad (11)$$

$$G_{CC} = E_8/E_C .$$

These choices of output measurement points introduce some loading effects because E_7 and E_8 are rather high impedance. The loading is estimated from nominal component values.

The voltage-to-frequency converters are calibrated statically. Our analysis shows a negligible phase angle.

The digital receiver response to input is described in terms of a timing diagram (Fig. 7). The counter start, stop and up-to-down times ($t_0, \dots, t_5$) are developed from the zero-crossing detector output CR and the rotation periods T_{n-1} and T_n .

The in-phase (I), quadrature (Q) and baseline (B) counter outputs (Fig. 6) are signed summations of the number of cycles of the phase lock loop (PLL) output that are counted during the counter reference signals CIR and CQR. Approximating the summations by integrals simplifies analysis. The following generation formulae are for the n^{th} rotation, where N is the appropriate PLL frequency multiplier and $F(t)$ is the frequency input to the PLL:

$$\begin{aligned} I_n &= N \int_{t_0}^{t_2} F(t) dt - N \int_{t_2}^{t_4} F(t) dt , \\ Q_n &= N \int_{t_1}^{t_3} F(t) dt - N \int_{t_3}^{t_5} F(t) dt , \\ B_n &= N \int_{t_0}^{t_4} F(t) dt . \end{aligned} \tag{12}$$

The times when the counter reference timing generator changes the states of CIR and CQR are

$$\begin{aligned} t_0 &= 0 , \\ t_1 &= \frac{1}{4} T_{n-1} , \\ t_2 &= \frac{1}{2} T_{n-1} , \\ t_3 &= \frac{3}{4} T_{n-1} , \\ t_4 &= T_n , \\ t_5 &= \frac{5}{4} T_n . \end{aligned} \tag{13}$$

Note that there is a significant phase shift between V_c and CR. Thus Q_n of the coil signal is nonzero.

The present processing models probe carrier frequencies for electric field and compass coil channels as follows:

$$F(t) = A \cos(\omega t + \phi) + C + Dt + Et^2 + \text{noise},$$

where A and ϕ are the amplitude and phase of the probe carrier frequency modulation and ω is the probe's radian rotation frequency. C, D and E allow for the exponential impulse response of the probe filters τ_1, τ_2, τ_3 (Fig. 2).

Expanding I, Q and B according to F(t) we have

$$\begin{aligned} I_n &= 2N \left[\frac{A}{\omega} \sin(\omega t_2 + \phi) + Ct_2 + \frac{1}{2} Dt_2^2 + \frac{1}{3} Et_2^3 \right] \\ &\quad - N \left[\frac{A}{\omega} \sin(\omega t_0 + \phi) + Ct_0 + \frac{1}{2} Dt_0^2 + \frac{1}{3} Et_0^3 \right] \\ &\quad - N \left[\frac{A}{\omega} \sin(\omega t_4 + \phi) + Ct_4 + \frac{1}{2} Dt_4^2 + \frac{1}{3} Et_4^3 \right], \\ Q_n &= 2N \left[\frac{A}{\omega} \sin(\omega t_3 + \phi) + Ct_3 + \frac{1}{2} Dt_3^2 + \frac{1}{3} Et_3^3 \right] \\ &\quad - N \left[\frac{A}{\omega} \sin(\omega t_1 + \phi) + Ct_1 + \frac{1}{2} Dt_1^2 + \frac{1}{3} Et_1^3 \right] \\ &\quad - N \left[\frac{A}{\omega} \sin(\omega t_5 + \phi) + Ct_5 + \frac{1}{2} Dt_5^2 + \frac{1}{3} Et_5^3 \right], \\ B_n &= N \left[\frac{A}{\omega} \sin(\omega t_4 + \phi) + Ct_4 + \frac{1}{2} Dt_4^2 + \frac{1}{3} Et_4^3 \right] \\ &\quad - N \left[\frac{A}{\omega} \sin(\omega t_0 + \phi) + Ct_0 + \frac{1}{2} Dt_0^2 + \frac{1}{3} Et_0^3 \right]. \end{aligned} \tag{14}$$

Time variations in ω significantly influence the counter outputs. In general, one must use the exact time intervals when processing. The

time intervals for I_n and B_n are the same (t_0, t_2, t_4), while those for Q_n are 1/4 cycle later (t_1, t_3, t_5). Normalization of counter outputs thus requires separate T_{In} and T_{Qn} :

$$\begin{aligned} T_{In} &= T_n , \\ T_{Qn} &= 5/4 T_n - 1/4 T_{n-1} , \\ T_{Bn} &= T_n . \end{aligned} \quad (15)$$

However, ω in the sinusoidal arguments is approximated by $\omega = 2\pi/T_n$, with a further approximation of $T_n/T_{n-1} = 1$ which results in

$$\omega t_i = \frac{\pi}{2} i , \quad i = 1, \dots, 5 . \quad (16)$$

The measured rms deviations of T_n/T_{n-1} appear to be bounded by 0.5% which roughly corresponds to 0.5% rms noise in I and Q. This seems acceptable at present.

In any case, this noise is included in the velocity error estimated from I'_n and Q'_n noise (see Eq. 19). Thus we can write, using $\omega = 2\pi/T$:

$$\begin{aligned} \frac{I_n}{N} &= - \frac{4A}{2\pi} T_{In} \sin\phi + C(T_{n-1} - T_n) \\ &\quad + D(1/2 T_{n-1}^2 - T_n^2)/2 + E(1/4 T_{n-1}^3 - T_n^3)/3 , \\ \frac{Q_n}{N} &= - \frac{4A}{2\pi} T_{Qn} \cos\phi + C(T_{n-1} - T_n)5/4 \\ &\quad + D(17 T_{n-1}^2 - 25 T_n^2)/32 \\ &\quad + E(53 T_{n-1}^3 - 125 T_n^3)/192 , \\ \frac{B_n}{N} &= C T_n + 1/2 D T_n^2 + 1/3 E T_n^3 . \end{aligned} \quad (17)$$

To solve for A and ϕ we find C, D and E from B_{n-1} , B_n , and B_{n+1} by solving a linear 3x3 matrix equation. The other values of B are:

$$\frac{B_{n-1}}{N} = C T_{n-1} - 1/2 D T_{n-1}^2 + 1/3 E T_{n-1}^3 , \quad (18)$$

$$\begin{aligned} \frac{B_{n+1}}{N} = & C T_{n+1} + D (T_n T_{n+1} + 1/2 T_{n+1}^2) \\ & + 1/3 E [(T_n + T_{n+1})^3 - T_n^3] . \end{aligned}$$

The corrected in-phase and quadrature results can then be determined:

$$\begin{aligned} I_n' &= - \frac{4ANT_{In}}{2\pi} \sin\phi , \\ Q_n' &= - \frac{4ANT_{Qn}}{2\pi} \cos\phi . \end{aligned} \quad (19)$$

To obtain averaged FM amplitude and phase, we convert to rectangular coordinates:

$$\begin{aligned} F_I &= - A \sin\phi = \frac{2\pi}{4NT_{In}} I_n' , \\ F_Q &= - A \cos\phi = \frac{2\pi}{4NT_{Qn}} Q_n' . \end{aligned} \quad (20)$$

Then we filter using a Bartlett (i.e., triangular) window with weights w_n :

$$\begin{aligned} \overline{F_I} &= \frac{2\pi}{4N} \sum_{n=1}^{Nav} w_n I_n' / T_{In} , \\ \overline{F_Q} &= \frac{2\pi}{4N} \sum_{n=1}^{Nav} w_n B_n / T_{Bn} . \end{aligned} \quad (21)$$

Baseline carrier frequencies are computed similarly:

$$\overline{F}_B = 1/N \sum_{n=1}^{Nav} w_n B_n / T_{Bn} . \quad (22)$$

Averaged amplitude F_a and phase F_p are found from $\overline{F}_I$ and $\overline{F}_Q$ by converting to polar coordinates using a four-quadrant arctangent function:

$$F_a = (\overline{F}_I^2 + \overline{F}_Q^2)^{1/2} , \quad (23)$$

$$F_p = \tan^{-1} \frac{-\overline{F}_I}{-\overline{F}_Q} .$$

Thus an input signal of $\cos(\omega t + \phi)$ will result in $F_p = \phi$. When $\phi > 0$, the input signal leads $\cos(\omega t)$. The reference is the zero-crossing-detector output CR.

Using phasor notation we write the complex frequency deviation in terms of amplitude and phase for both the electric field and compass coil.

$$F_E = F_{Ea} \angle F_{Ep} , \quad (24)$$

$$F_C = F_{Ca} \angle F_{Cp} .$$

Using (10) we compute the complex voltages at the probe input:

$$E_E = E_{Ea} \angle E_{Ep} , \quad (25)$$

$$E_C = E_{Ca} \angle E_{Cp} .$$

The east and north velocities are found as

$$\begin{aligned} u &= \frac{E_{Ea}}{F_Z L(1+C_1)} \cos \psi , \\ v &= - \frac{E_{Ea}}{F_Z L(1+C_1)} \sin \psi + W \frac{F_H (1+C_2)}{F_Z (1+C_1)} , \end{aligned} \quad (26)$$

where

$$\begin{aligned} \psi &= \beta_E - \beta_C + \pi/2 + \alpha , \\ \beta_E &= - E_{EP} , \\ \beta_C &= - E_{CP} , \\ \alpha &= \pi . \end{aligned} \quad (27)$$

W is the estimated fall rate, dz/dt , of the probe computed from a depth versus time polynomial.

Depth versus time was measured using five special probes with pressure transducers instead of thermistors. An average quadratic was fit to these measurements for use in determining Z and W versus time during processing.

$$P = -Z = 3.1 + 4.544t - 0.0006749t^2 . \quad (28)$$

A "tilt" correction (discussed in section V.C.) is applied to the north velocity component to remove effects caused by north-south probe tilt. The "area" A of the coil is computed assuming no probe tilt:

$$A = \frac{E_C T}{2\pi F_H} , \quad (29)$$

where T is the rotation period, E_C is the coil signal, and F_H is the earth's horizontal magnetic field.

Individual corrected estimates of the north velocity component are found by using

$$V = - \frac{E_{EA}}{F_Z L (1+C_1)} \sin \psi + W \frac{F_H (1+C_2)}{F_Z (1+C_1)} \frac{A}{\bar{A}}, \quad (30)$$

where $\bar{A}$ is the vertical mean of A .

3. Plotting and Analysis Programs

a. SPLIT

SPLIT is used to obtain more insight into the profiles. It plots a series of U , V profiles with various processing applied. Generally a quadratic fit is performed on the profile to obtain the residuals. These can be rotated to a given time by specifying the inertial period and the time of each profile. Cartesian or polar displays are available. One can also plot the fits.

b. CROSS

CROSS will compute cross-correlations, structure functions, or coherences between U and V profiles. Input is set up in advance, and then processing continues unattended. Many sets and combinations of files can be processed in a single run.

E. PROBE CALIBRATIONS

1. Sippican's Calibration

The XTVP gains $G_{EF} = E_7/E_E$, $G_{COR} = E_7/E_C$, $G_{CC} = E_8/E_C$, $G_{EFVP} = F_E/E_7$ and $G_{CCVF} = F_C/E_8$ are measured during manufacture before potting. Figure 9 shows the test setup to obtain G_{EF} , G_{COR} , and G_{CC} . The operator adjusts the quadrature potentiometer $P = R_7/(R_6 + R_7)$ and the resistance box R_2 to obtain a null reading on both the I and Q meters of the PAR 129. This forces

$$G_{ATTEN} \cdot G_{PROBE} = 1 / \phi_{PAR}, \quad (31)$$

where ϕ_{PAR} is the phase offset of the PAR 129. The Sippican calibration estimates $G_{\text{PROBE}} = R_2 + 100$, which is a result of considering only the resistive part of the attenuator. Further analysis of the attenuator transfer function shows that this estimate is about 3% too large for G_{EF} and G_{COR} because approximately 15° phase angles exist at 7 Hz. The exact error depends on ϕ_{PAR} . Table 3 shows results of the analysis where P and R_2 were adjusted to obtain analytic probe gains and phases.

Table 3.

	$P = R_7/(R_6+R_7)$	R_2	$\frac{1}{ G_{\text{ATTEN}} }$	$-\phi_{\text{ATTEN}}$	% error of $R_2 + 100$
G_{EF}	0.0244	25278	24495	15.2°	3.5%
G_{COR}	0.525	1036	1097	15.3°	3.5%
G_{CC}	0.011	3598	3698	1.0°	0.0%

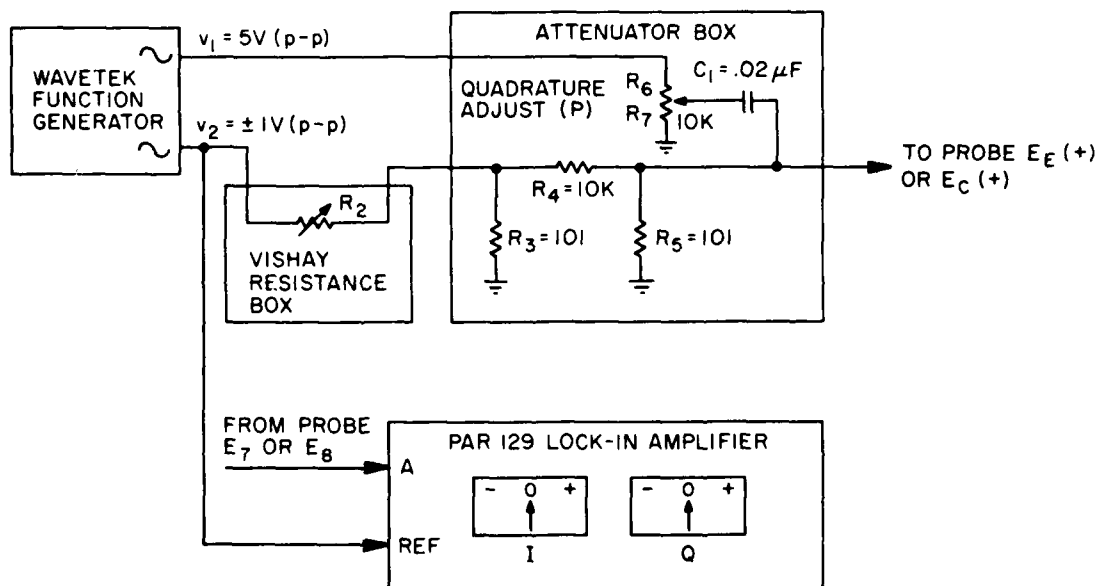


Figure 9. Standard setup used by Sippican for probe calibrations.

These estimates assume $\phi_{\text{PAR}} = 0$. Our PAR 129 indicates -3° to -5° with dials set to 0° . Sippican's PAR 5204 indicates a value closer to 0° . For correct results, the PAR dials should be set so that the Q meter indicates zero for the signal equal to the reference.

Obtaining the correct G_{PROBE} requires knowledge of the quadrature adjust potentiometer P, which is not recorded. However, if ϕ_{PAR} is zero, we can estimate ϕ_{ATTEN} from a ϕ_{PROBE} obtained from a transfer function analysis of a typical probe.

From the computer analysis of the attenuator gain we find that $1/(R_2 + 100)$ approximates the real part of G_{ATTEN} quite closely. Thus a better estimate for the gain magnitude of the probe is

$$|G_{\text{PROBE}}| = (R_2 + 100) \cos(\phi_{\text{PROBE}}) . \quad (32)$$

G_{EFVP} and G_{CCVF} are found statically by applying $+0.5$ V and then -0.5 V to both E_7 and E_8 while recording the voltage-to-frequency converter output frequencies F_E and F_C . The change in frequency divided by the change in voltage provides the estimate for G_{EFVP} and G_{CCVF} .

Early calibrations had a 1K resistor in series with the ± 0.5 V source. Thus the early Sippican G_{EFVF} and G_{CCVF} estimates were low by 3.3% and 1.7%, respectively. In May 1980 the 1K resistor was removed from the setup.

2. APL-UW's Calibrations

The calibrations described in the previous section are time consuming. A simplified calibration procedure is used by Sippican Corp. in the manufacture of XCP's. We wanted to verify their calibrations to eliminate uncertainties in the velocity determination. We also wanted to be able to correct old calibrations by finding any systematic differences. Therefore, ten unpotted, Sippican-calibrated probes were purchased for our measurements.

Our calibrations (Fig. 10) were done with both channels of the probe having nominal signal amplitudes at all times rather than setting one channel to zero input while measuring the other as Sippican did. Our input signals were exactly in phase however, due to lack of test equipment. (We would have liked to check for cross-talk and non-linearity.)

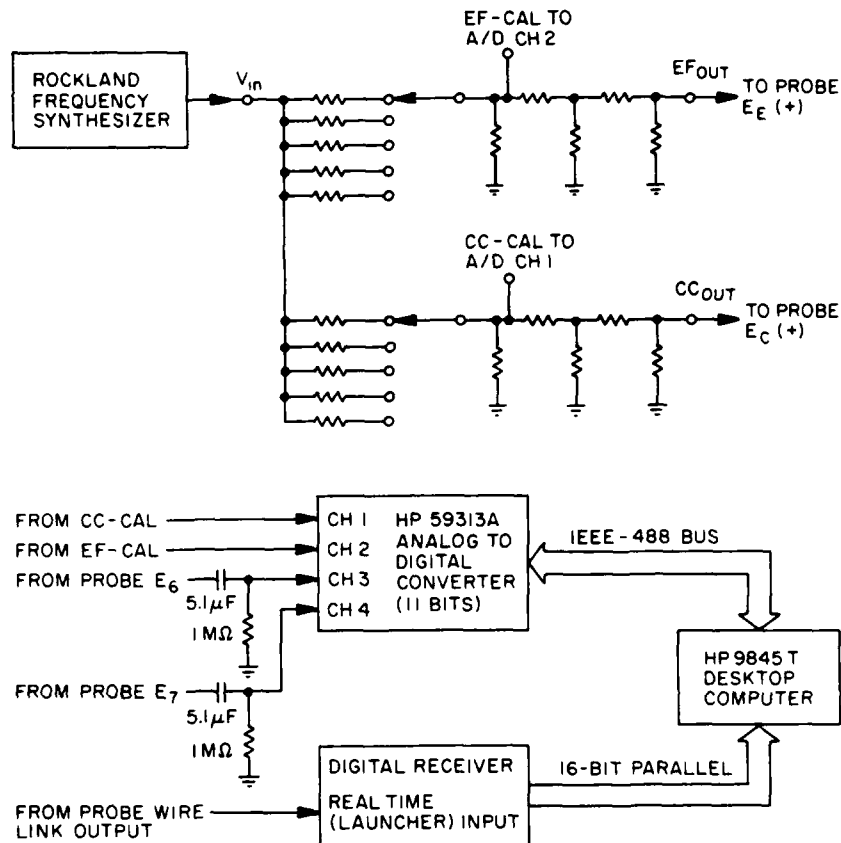


Figure 10. Special setup used by APL-UW for probe calibrations.

To check the Sippican calibrations, we wanted to measure the probe at the same points. However, this meant loading E_7 and E_8 (Fig. 2) and thus changing the overall transfer functions. We therefore measured at E_5 and E_6 , and estimated the transfer functions to E_7 and E_8 .

Note that in the future these intermediate points need not be measured; only the three overall transfer functions, $G_{EF} G_{EFVF}$, $G_{COR} G_{EFVF}$, and $G_{CC} G_{CCVF}$ will be needed.

Because only single-ended test signals with a common reference were available, the drive signal should go to the "plus" (noninverting) inputs of E_E and E_C . This procedure reduces drive signal loading and tests all the components.

The measurement points EFCAL and CCCAL are needed since there is significant interaction between the two attenuator-adjust switches. The attenuations from EFCAL and CCCAL to EFOUT and CCOUT are estimated stagewise using a dc source and a digital voltmeter.

The ac coupling to channels 3 and 4 of the HP 59313A digitizer isolates its input bias current from the probe. These transfer functions are allowed for in the analysis.

The HP 59313A digitizer multiplexes the analog to digital converter between four input channels. The time differences between channels are corrected by adjusting the phase angles of the sinusoidal fits during analysis.

The digital receiver is used in the real-time mode. The acquisition program sets up a direct memory access from the receiver. This runs concurrently with input from the digitizer. Each channel's sample rate is limited to 5 Hz by the speed of the HP 9845 desk-top computer.

Operation is not fully automatic due to lack of equipment: the operator is required to change the attenuator settings manually for each "set" in a "run." Typically, four linearly independent sets of attenuator settings are used per calibration run, although the program can handle nine sets.

Following acquisition, the processing runs unattended for several minutes to compute gain estimates for that run. We made from 5 to 15 runs per probe to observe the variability of the method and obtain reliable results.

To obtain amplitudes and phases of the digitizer channels, they are least-squares fit to

$$a_1 + a_2 \cos \omega t + a_3 \sin \omega t + a_4 (t - \bar{t}), \quad (33)$$

where ω is the radian frequency, $\bar{t}$ is the mean t and $a_1, \dots, a_4$ are the coefficients determined by the "set." ω is found by iterative adjustment to obtain phase continuity between successive blocks of the CC-CAL channel. The procedure is identical to that described by Sanford et al. (1978). The amplitude A and phase ϕ are

$$A = (a_2^2 + a_3^2)^{1/2} ,$$

(34)

$$\phi = - \tan^{-1} \frac{a_3}{a_2} .$$

The amplitude and phase angle of each sinusoidal fit and the average I and Q from the receiver were then least-squares fit to a linear model of complex probe gains:

$$E_7 = G_{EF} E_E + G_{COR} E_C ,$$

$$E_8 = G_{CC} E_C ,$$

$$F_E = G_{EFVF} E_7 ,$$

(35)

$$F_C = G_{CCVF} E_8 ,$$

$$F_E = (G_{EFVF} G_{EF}) E_E + (G_{COR} G_{EFVF}) E_C ,$$

$$F_C = (G_{CC} G_{CCVF}) E_C .$$

The first four expressions are to be compared with Sippican's, while the last two are used to find the overall transfer functions of the probe.

The receiver counters average over each revolution, so the measured F_E and F_C are quieter than E_7 and E_8 which are only sampled once per 200 ms. Thus, the overall transfer functions can be determined more accurately and with less effort than the individual transfer functions.

The circuit gains (e.g., G_{EFVF}) are complex coefficients a_j in models of the form

$$y = \sum_{j=1}^m a_j x_j ,$$

(36)

where y is the output and the x_j 's are the inputs.

To solve for the a_j 's, several linearly-independent "sets" of y versus x_j are required. Each measured output y_i is related to the inputs x_{ij} as follows:

$$y_i = \sum_{j=1}^m a_j x_{ij} + r_i, \quad \text{for } i = 1, \dots, n \quad (37)$$

where n is the number of sets and the r_i are the residuals. The complex gains a_j are found by least-squares fitting in a manner similar to the sinusoidal fitting.

For each probe, the gains were averaged over a number of runs. These averages include only those runs with low fit noise and low receiver noise.

Multiple short runs enabled elimination of bad sections of data instead of repeating an entire long run. Multiple runs also allowed an estimation of the reliability of the method. The sinusoidal fits are less sensitive to the rotation frequency estimate when the fits are shorter.

Our measurements indicate that the complex gains from probe to probe are quite similar, within 0.4% in magnitude and 0.4° in phase, as summarized in the standard deviations in Table 4.

Table 4.

	Amplitude Deviation from Analytic (%)		Phase Deviation from Analytic (°)	
	Avg.	Std. Dev.	Avg.	Std. Dev.
G_{EF}	0.2	0.1	- 0.2	0.2
G_{COR}	-1.6	0.4	- 0.1	0.4
G_{CC}	-1.8	0.1	- 0.3	0.0

Note, however, that the averages for G_{COR} and G_{CC} amplitudes differ significantly from the analytic estimates.

Our measurements deviate from Sippican's using $|G_{PROBE}| = (R_2 + 100) \cos(\phi_{PROBE})$ as summarized in Table 5.

Table 5.

Amplitude
Deviation from
Sippican's (%)

	Avg.	Std. Dev.
G_{EF}	0.6	0.1
G_{COR}	1.3	0.5
G_{CC}	0.2	0.2

The G_{EF} and G_{COR} errors are significant and would be smaller if the Sippican PAR phase error were 1° as summarized in the following table.

Table 6.

Amplitude Deviation (%)
from Sippican's Assuming
 1° PAR Error

	Avg.	Std. dev.
G_{EF}	0.0	0.1
G_{COR}	0.8	0.5
G_{CC}	0.2	0.2

Our estimates of G_{EFVF} and G_{CCVF} show relatively small variability from probe to probe compared with Sippican's measurements for the same nine probes. The following table summarizes.

Table 7.

	Our V/F Estimates		Sippican's V/F Estimates Allowing for 1K Resistor		Deviations of Our Estimates From Sippican's
	Avg. (Hz/volt)	Std. Dev. (%)	Avg. (Hz/volt)	Std. Dev. (%)	(%)
G_{EFVF}	994	0.2	1000	1.0	-0.6
G_{CCVF}	1001	0.1	1000	0.6	0.1

The general conclusion about the calibration problem is that future designs should eliminate the need for calibration, or, if needed, make it automatic with frequent verification of the test setup.

We have not attempted to answer the question of how the calibrations change with potting or depth. There is some reason to believe potting may affect the V/F converter calibration. We have not determined why the measured gains differ from the analytic estimates.

F. SENSITIVITY ANALYSIS OF PROBE

Sensitivity analysis of the XTVP probe is performed using the analytic transfer functions for the probe while varying the component values. We have not shown sensitivities for individual components; rather we have computed the variability of the probe transfer functions as a function of component tolerances. We have not shown statistics for the V/F converters.

The component tolerances are used to choose random component values. Uniform distributions were used for simplicity. Typically 20 realizations of the transfer function with independent random component values are used.

The maximum, minimum, average and standard deviation for the amplitude and phase of each transfer function are computed given the rotation frequency and component tolerances using a computer program.

Table 8 shows deviations at 7 Hz using standard component tolerances of 0.1% resistors and 10% capacitors.

Table 8.

	Amplitude			Phase		
	Avg.	rms(%)	Max-Min(%)	Avg.	rms(%)	Max-in(%)
G_{EF}	24333	0.13	0.28	15.2	0.5	2.1
G_{COR}	1096	0.15	0.26	-165.0	0.5	2.0
G_{CC}	3696	0.13	0.22	-179.0	0.06	0.21

If 1% resistors and 10% capacitors are used, the amplitude deviations increase while the phase deviations remain the same, as can be seen in the following table.

Table 9.

	Amplitude			Phase		
	<u>Avg.</u>	<u>rms(%)</u>	<u>Max-Min(%)</u>	<u>Avg.</u>	<u>rms(%)</u>	<u>Max-Min(%)</u>
G _{EF}	24568	1.1	5.0	15.2	0.5	2.0
G _{COR}	1094	1.7	5.9	-165.0	0.5	2.0
G _{CC}	3682	1.2	4.0	-179.0	0.05	0.25

An attempt to determine the pressure variability uses 0.5% capacitor deviations and no resistor deviations (Table 10).

Table 10.

	Amplitude			Phase		
	<u>Avg.</u>	<u>rms(%)</u>	<u>Max-Min(%)</u>	<u>Avg.</u>	<u>rms(%)</u>	<u>Max-Min(%)</u>
G _{EF}	24494	0.00	0.00	15.2	0.005	0.02
G _{COR}	1097	0.00	0.01	-165.1	0.005	0.02
G _{CC}	3697	0.00	0.00	-179.0	0.001	0.002

IV. Operations

A. EQUIPMENT INVENTORY

Table 11 lists the equipment that was shipped to support the deployment of about 50 XTVP's from the USNS Kane.

Table 11.

Box #	Contents	Function	Weight (lb)
1.	a) PAR Lock-in Amplifier	Resolves analog U and V velocity components	
	b) HP 3960 Analog Tape Recorder	Records FM signals during drop	
	c) Sippican Digital Receiver	Determines digital U and V velocity components; sends data to 9845 computer	291
2.	a) Tektronix TM506 Mainframe		
	1) PS 503A Power Supply incl.	Repair and calibration equipment	
	2) FG 501 Function Generator		
	3) DC 503 Counter/Timer		
	4) DM 501 Multimeter		
	5) SC 502 Oscilloscope		
	b) HP 3964 Analog Tape Recorder	Spare recorder for FM signal storage	
	c) APL-UW Digital Receiver	Spare receiver to Sippican made unit	
	d) HP 7046A XY Plotter	Analog plotter for real time display	305 (total)
3.	a) HP 9845T Computer (CRT)	Digital acquisition and processing	50

Box #	Contents	Function	Weight (lb)
4.	a) HP 9845T Computer (CPU)	Digital acquisition and processing	101
5.	a) HP 9872A Plotter	Plots digital U,V profiles	94
6.	a) HP 9885M Disk Drive	Digital storage for raw and processed profiles	128
7.	a) HP 98034A HP-IB Interface b) HP 98035A Opt. 100 Real Time Clock c) HP 98032A 16-bit I/O APL-UW d) HP 98032A 16-bit I/O Sipp. DR e) Fluke 8024A Multimeter f) HP 32E Calculator g) Misc. Electronic Spares	9845T computer peripheral and interface cards Test Hand calculator Repair	75
8-10.	a) Floats (Ethofoam) (3 boxes used because of bulk)	For XTVP surface flotation (Total 3 boxes)	50
11.	a) Misc. Support Equipment	--	100
12.	a) 10 Mag. Tapes for Analog Recording b) 50 Cassettes for Digital Recording c) 4 boxes Graph Paper for Analog Plots d) 1 box Xerox Paper	Supplies " " "	109
13.	a) 10 Mag. Tapes for Analog Recording b) 25 Diskettes (8 1/2" IBM) for Digital Recording c) 4 boxes Graph Paper for Digital Plots d) 1 box Xerox Paper e) 1 Tool Box - Misc. Hand Tools f) 1 XTVP Log Book	Supplies " " " "	84

Box #	Contents	Function	Weight (lb)
14.	a) Tektronix 7603R Oscilloscope	FM data display	
	b) 7A22 Plug-In Amplifier	"	
	c) 7A26 Plug-In Amplifier	"	
	d) 7B23 Plug-In Time Base	"	85
15.	a) Launcher Tube Ends	} For launching tube assembly	73
	b) Adaptor Tubes		
	c) Metal Hose Clamps and Hardware		
16.	a) 2 Sippican Hand Launchers	XTVP launcher	
	b) Deck Cable	"	
	c) Misc. Cables	"	
	d) Scope Probes	"	89
17.	a) 1 Garbage Can	For on-deck check	
	b) Anti-hypothermia Suits	Personnel protection	24
18.	a) 5 LEXAN Tubes, 2 1/2" x 9'	For deck launcher	10
19.	a) Box Misc. Stores		57
20.	a) Probes (12/box)		50
21.	a) Probes		50
22.	a) Probes		50
23.	a) Probes		<u>50</u>
TOTAL SHIPPING WEIGHT			1,925

This equipment comprises both analog and digital processing instrumentation including spare data receivers, analog tape recorders and launch hardware.

B. INSTALLATION OF XTVP SHIPBOARD LAUNCH AND RECEIVING SYSTEM

1. Deck Setup

- a. Determine exact weather deck location where probes will be launched. Some (but not all) of the factors that will fix this position are:
 - 1) Concurrence of Chief Scientist and Chief Bos'n (or equivalents)
 - 2) Consideration of other scientific projects on same cruise
 - 3) Distance from assigned laboratory space
 - 4) Type of ship
 - 5) Wind/weather expected, and its influence on launching operations
 - 6) Sufficient space aft of launcher loading position to swing launcher tube inboard in order to load probes and attach flotation collars.
- b. Assemble LEXAN launcher tube (usually two 9' sections are enough, unless ship's rail is >10' above waterline). Attach launcher loading end to ship's rail (Pos. A) so outer end can be swung inboard for loading and outboard for launching. Attach all necessary support and securing lines. Prepare a release line and leave coiled at point where launcher end is brought inboard (Pos. B). Secure a 30 gal. plastic garbage can at ship's rail at (Pos. A). Fill to ~16" with clean seawater.
- c. The Sippican hand launcher and intercom (currently Radio Shack # 43-221) are needed at Pos. A.
 - 1) The hand launcher is usually hung on a bulkhead hook or equivalent, to protect it when not used in the launching tube, with about 10' of slack cable to enable probes to be tested in the plastic bucket.
 - 2) The intercom is secured in a suitable location at about head height, using a convenient stanchion or bulkhead. Note that this unit is not waterproof. During inclement weather or high sea states it should be stored in the lab when not being used; thus a "shock cord" (quick release) type of attachment should be used.
- d. The launcher and intercom wires must be routed to the lab operating area. Considerable care must be taken to avoid hazards that may injure the wires. If possible, an overhead or bulkhead route is preferable to a deck route.

2. Laboratory Setup

- a. Determine from Chief Scientist the maximum available bench and deck space.
- b. Set up communications link to bridge (mandatory), and radio room and chartroom if possible.
- c. Bench space allocation should be:
 - 1) HP 9845T computer ~20" wide
 - 2) HP 9872A digital plotter and HP 9885M disc drive are mounted together vertically ~20" wide
 - 3) HP 7046B analog plotter (if used) ~19" wide
 - 4) Approximately 30" of bench area for writing
 - 5) If more bench space available, some of the following items listed as rack mounted may be used in 36" high racks which can usually be mounted on top of the bench.
- d. Rack space. The following is a "top-to-bottom" guide.
 - 1) HP 3964 analog tape recorder - must be accessible to load and unload tapes.
 - 2) PAR 129A lock-in amplifier - occasional changes in control settings will be made on this unit.
 - 3) Tektronix TM 506 mainframe scope - check to ensure electric field and compass signals are present.
 - 4) XTVP digital receiver - once connected, usually no changes need be made to this unit.
- e. If additional rack space is available, the backup HP 3960 analog tape recorder and XTVP-DR should be mounted so as to allow a quick switch if the primary units malfunction.
- f. Boxes of expendable supplies (probes, magnetic tape, plotting paper, etc.) should be stored in the lab area if possible for easy access during the cruise. Boxes of spare parts or seldom used items may be stored in a hold or other nonlab area.
- g. Before sailing, all items must be properly secured in accordance with good seamanlike practice. The Chief Boatswain (or equivalent) can advise and assist, and may be able to suggest improvements, etc.
- h. Try to do a dummy drop, testing a probe in a bucket, etc. and communicating with bridge, radio room, engine room, etc. before the cruise begins. All installations, rigging and testing are more easily done alongside the dock.

C. SUMMARY OF XTVP LAUNCH AND OPERATIONS

1. General Instructions to Bridge

- a. Establish communications channels.
- b. Emphasize radio silence for bridge and radio room.
- c. Emphasize speed requirements (must be less than 8 knots). In high winds, head into wind/seas to prevent paying out too much wire.
- d. Provide the bridge with written instructions and a copy of this summary if possible.

2. Pre-Launch Procedure

- a. Operator gives bridge desired position for next drop and asks for 5 minute warning.
- b. Launch person picks out a probe, writes serial number in the drop log, puts probe in hand launcher, removes magnet (turns on), puts probe into bucket of seawater and waves magnet in the vicinity of the electrodes (not to turn on and off, but to induce a signal in the coil channel). Lab confirms presence of FM carriers, and that V_C and V_E deviates with magnet. Launch person replaces magnet (turns off).
- c. When ready for launch, lab person comes to the deck to help put probe in launcher (a second person is needed to catch the probe as it falls down launch tube). Fuse and float are attached to the probe (see Appendix B), and then complete unit is secured in launcher. Lab person returns to the lab.
- d. Lab person puts voice header onto the analog magnetic tape (e.g., STREX '80, drop number, probe number), and loads acquisition program into HP 9845 computer.
- e. Bridge informs lab that the ship is on or approaching station.
- f. Lab acknowledges and requests radio silence for bridge and radio room.
- g. Lab informs deck to launch when ready.

3. Launch Operations

- a. Deck operator informs lab that it's 10 seconds to launch, lights fuse, and hollers into intercom. Lab operator starts analog tape recorder, 9845 acquisition program, and elapsed time counter (model DC 503 timer-counter).
- b. Fuse burns at 120 seconds per yard; 27 inches (about 80 to 90 seconds) was used during STREX.
- c. The end of the fuse is bent at 90 degrees and thrust into the Ethafoam float to prevent the fuse from rotating. See Appendix B for construction details.
- d. Launcher is lowered down toward the waves.
- e. Operator waits for a high wave so that the probe will only drop 1 to 2 feet from the launcher into the water.

4. Data Acquisition and Processing

- a. Turn on HP 9845 with AUTOST key locked down and the system cartridge in T15 (right-hand cartridge slot).
- b. Press special function key "k₀" to load and start DXGET, the acquisition program. Press CONT again when probe is launched.
- c. After the drop is completed, type the file name for the disk file to store data and add comments to the real time when DXGET was started.
- d. Earth's magnetic field can be found using the PADO program. PADO requires the date and position as input.
- e. To process the disk file, press special function key "k₁" to load and start DXPRO, the processing program. Answer the prompts with the appropriate file names and probe numbers. Add the drop and earth's magnetic field to the calibration data found on the XCAL file. Processing will take about 20 minutes to obtain a completed plot.

5. Post-Launch Procedure

- a. Lab advises bridge that the probe has been dropped, and the time is entered in the bridge log.
- b. Operator writes the time which appears on the 9845 CRT display.

- c. Ship continues for 2 min at the same course and speed, after which it is told to come into the wind and sea and essentially maintain direction.
- d. At the end of the drop, the wire breaks at the hand launcher so that no wire is left in the tube.
- e. The XBT wire canister stays on launcher until next drop to protect launcher contacts.
- f. The operator writes down the elapsed time from when the fuse was lit to the time the wire broke.
- g. Operator logs the end-of-drop count from the analog tape recorder.
- h. Operator notifies bridge that drop has been completed and that there is no need for further radio silence.

V. Error Analysis

A. CONTAMINATION OF XTVP PROFILES FROM VESSEL'S EM FIELDS

Contamination of XTVP velocity measurements is severe in the near vicinity of large research vessels. Based on the simple dipole character of vessel fields, our rule of thumb has been to release a probe 1-2 ship lengths away. This section describes some recent analyses to assess the amount of contamination found during two recent experiments.

Separation of vessel-caused disturbances from the desired motionally induced field is possible only because the former can be so large. Near the ship we frequently find electric currents that are interpreted as due to a velocity in excess of 10^3 cm/s. Since there are no ocean flows of this speed, we can assume this velocity is due to the vessel and compare it with a model.

The model used is a horizontally oriented current dipole at the sea surface aligned with the vessel. The idea here is that electric currents exist around the vessel because of corrosion and cathodic protection. The latter cause probably will be dipole-like and of rather small scale. The horizontal and vertical electric current density in the area would be

$$J_x = \frac{2p}{4\pi} (2x^2 - z^2) / (x^2 + z^2)^{5/2}, \quad (38)$$

$$J_z = \frac{6pxz / (x^2 + z^2)^{5/2}}{4\pi}, \quad (39)$$

where p is the dipole strength in ampere meters. These expressions are twice those found for a dipole in an infinite medium because the current is confined to only the lower half domain.

For a ship speed of 5 knots and a fall speed of 4.5 m/s (say 10 knots), the horizontal position of the probe will increase at a rate of 0.5 W or $x = a + 0.5 z$, where a is the distance of release from the center of the dipole.

The XTVP measures the horizontal component of the electric current as

$$J_x/\sigma = \frac{p(1+\xi-\xi^2/4)}{a^3 \pi \sigma (1+\xi+5\xi^2/4)^{5/2}}, \quad (40)$$

where σ is the electrical conductivity and $\xi = z/a$. The electric current is connected to velocity by the relation

$$V_y = \frac{J_x}{F_z \sigma} = \frac{p(1+\xi-\xi^2/4)}{a^3 \pi F_z \sigma (1+\xi+5\xi^2/4)^{5/2}} \text{ m/s}. \quad (41)$$

One aspect of this expression to note is that $J_x/\sigma = 0$ at a depth of $z = 2a(1+\sqrt{2}) = 4.8 a$. A near-surface notch, or low-signal zone, is frequently observed in the Kane and other near-vessel dropped profiles. This is because the electric currents lines are curved and must become vertical as they converge toward the source and sink. A probe will experience this zone of zero horizontal electric currents at a depth of $z = 4.8 a$. Thus we would expect it to be seen at deeper depths for large release separations. Note also that the sign of J_x changes at $z = 4.8 a$.

Figures 11 and 12 show two drops from the September 1979 Kane experiment. An example is shown for the SE-NW leg and for the NE-SW leg, two different orientations of the ship with respect to the earth's magnetic field. The absolute values of east (u : dashed), north (v : dash-dot) and speed [$(u^2 + v^2)^{1/2}$: solid] are plotted versus depth. The near-ship notch is seen in both figures, and a signal decay of about z^{-3} is observed as expected. At a depth of 30 m and deeper, the ocean-induced signal seems to dominate.

Figures 13 and 14 show two other drops, one from the remote launcher and another from the towed rubber boat. Neither of these profiles shows the vessel signature. They quickly converge on a signal level of 20-30 cm/s, which is the ocean contribution.

In Fig. 15, a comparison of the data of Fig. 11 is made with a fit [i.e., the absolute value of (41)] of the model for $p/\pi F_z \sigma = 4.9 \times 10^4$ which corresponds to $p = 30.8$ A-m, and for $a = 1$ m. A current dipole moment of this amount is typical for ships of this size. The model and data agree reasonably well until the ocean field takes over at 20 m. It should be emphasized that the model predicts >1 cm/s error until a depth of ~ 100 m.

Curves are of east (dashed), north (dash-dot) and speed (solid).

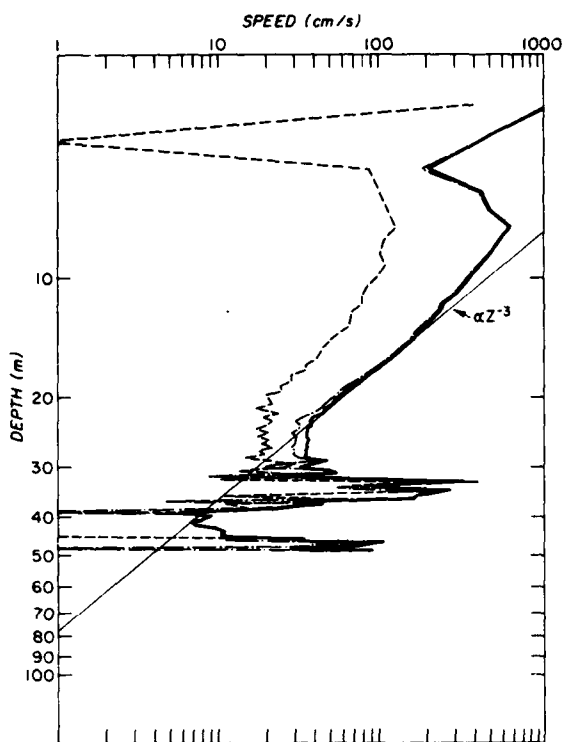


Figure 11. Drop 281 USNS Kane, deck launched. Dipole-like decay is shown as z^{-3} .

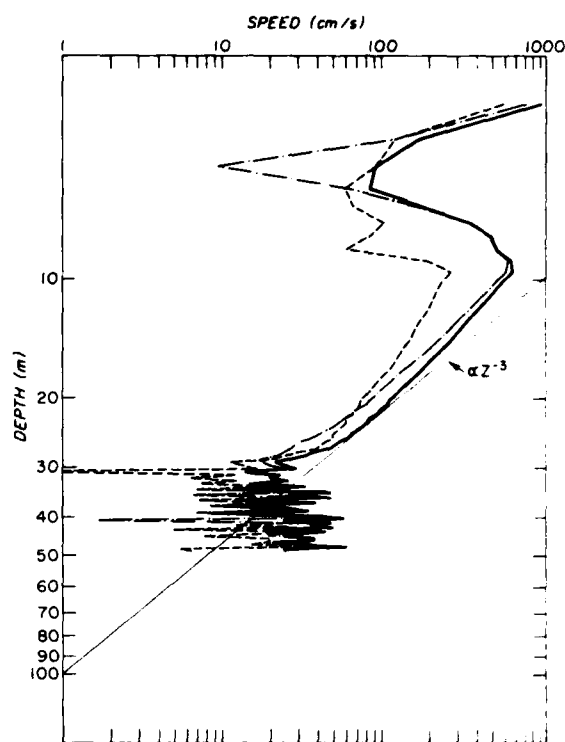


Figure 12. Drop 274 USNS Kane, deck launched. Dipole-like decay is shown as z^{-3} .

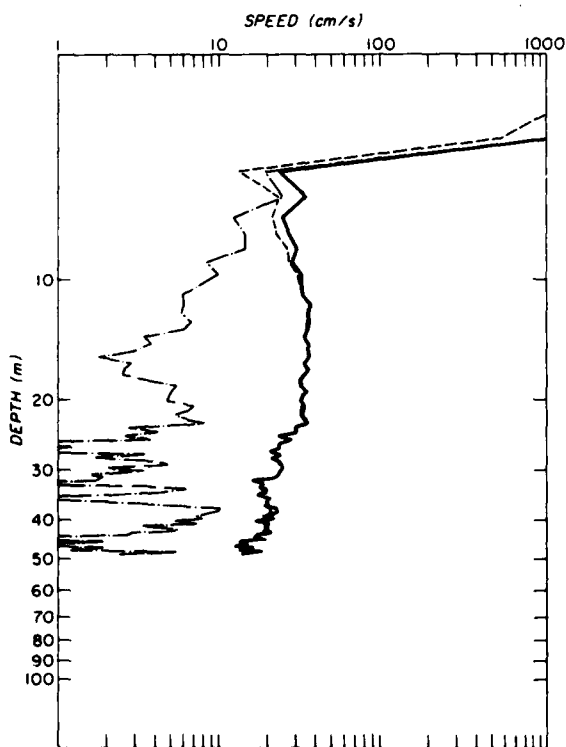


Figure 13. Drop 276 USNS Kane, remote launched.

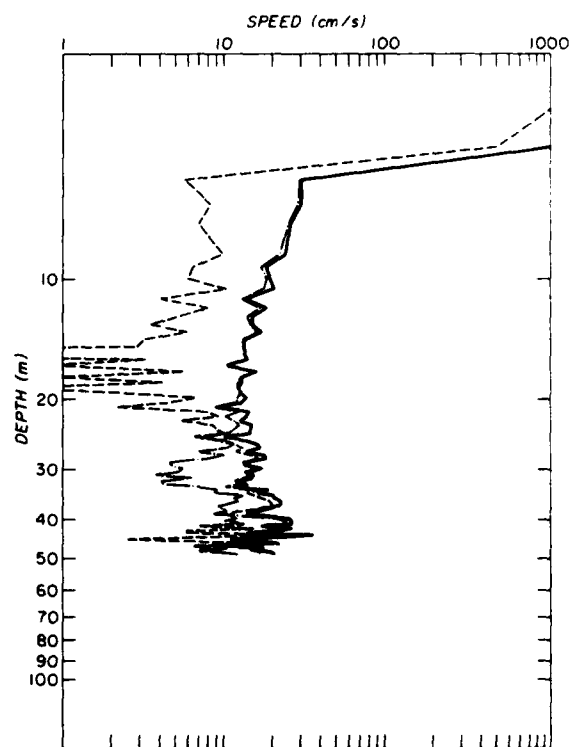


Figure 14. Drop 299 USNS Kane, rubber boat launched.

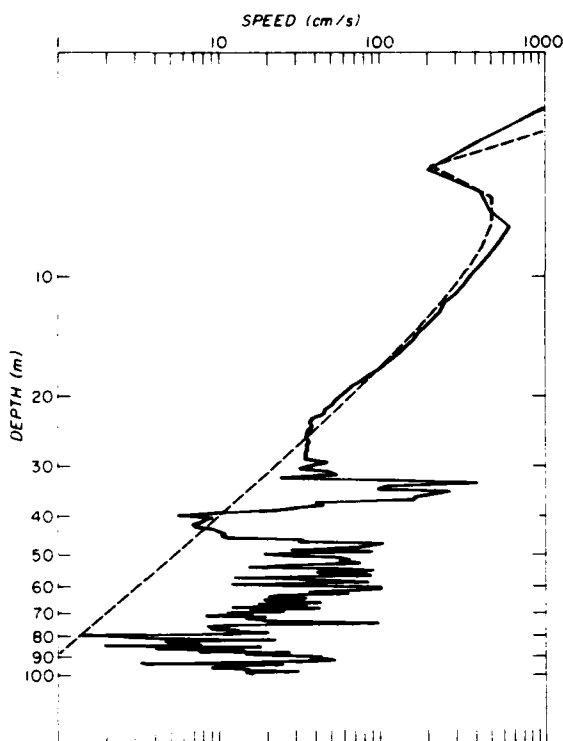


Figure 15. Drop 281 USNS Kane, deck launched. Profile of speed compared with dipole influence model.

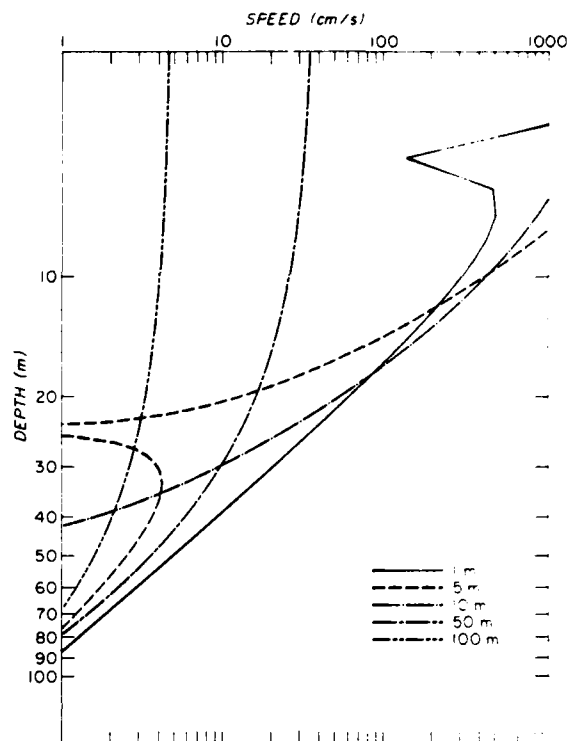


Figure 16. Dipole influence for $a = 1, 5, 10, 50$ and 100 m.

The model can be used to predict interference from the ship as a function of a , the distance of the release point from the ship. Figure 16 presents these results for $a = 1, 5, 10, 50$ and 100 m for $p = 30.8$ A-m. As expected, the level of interference and the depth of the notch change as a is increased. These calculations show that, even for $a = 100$ m, the interference is about 3-5 cm/s until a depth of 60-70 m. In order to limit the errors to <1 cm/s it seems that $a \approx 170$ m is needed. Caution should be used in interpreting these results, since the model is rather crude and is based on only one calibration. On the other hand, p is reasonable in its strength, and the results are comparable to our rule of thumb.

Two examples, Figs. 17 and 18, of data and model fits are shown for drops launched from the starboard rail of the NOAA Oceanographer. In this case, a current dipole of 30.8 A-m was again used, but $a \approx 2.5$ m. Again the fit is reasonably good, and a predicted interference exceeds 1 cm/s until a depth of ~ 150 m. The larger depth scale for the Oceanographer versus the Kane is in the sense of their lengths, but this result may only be fortuitous, since vessel length does not enter the model.

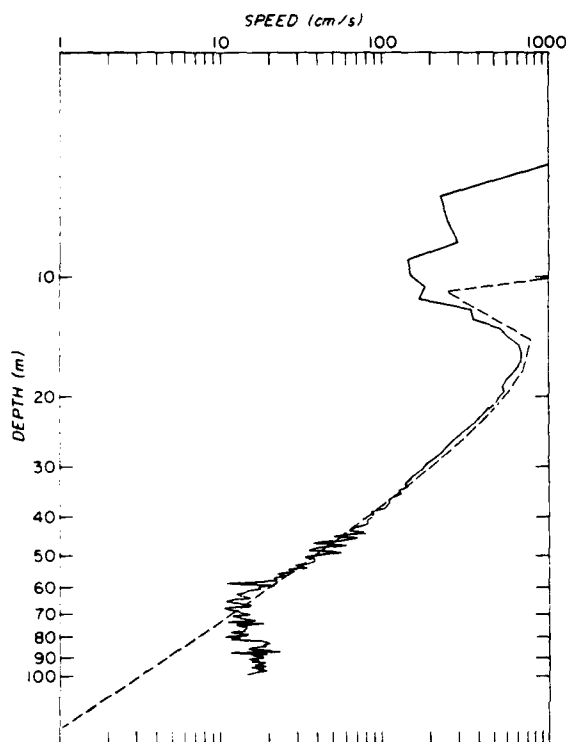


Figure 17. Drop 438 NOAA Oceanographer, deck launched. Profile of speed compared with dipole model.

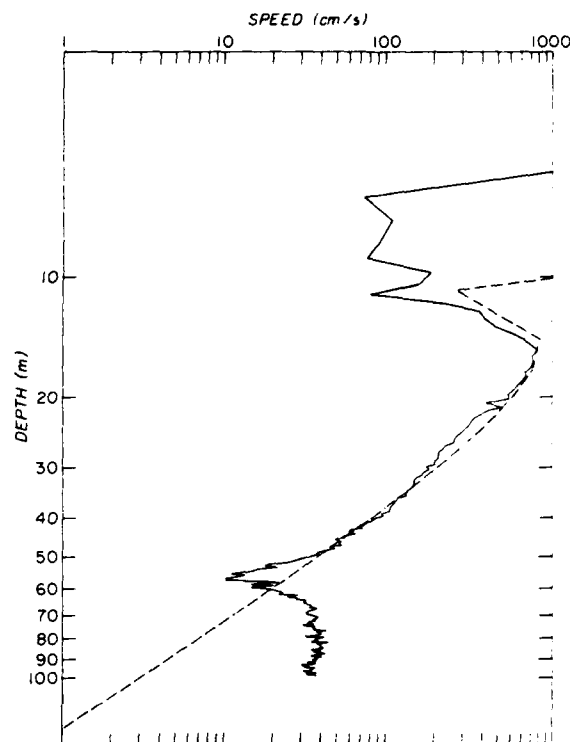


Figure 18. Drop 396 NOAA Oceanographer, deck launched. Profile of speed compared with dipole model.

Finally, the influence of the magnetic distortion of the Kane was examined. In Fig. 19, the magnitude of the coil area is shown for a sampling of differently launched profiles. The coil area is used as a measure of magnetic disturbance. It is also sensitive to tilt, which makes the interpretation of this signal somewhat ambiguous. Nonetheless, if the ship distorts the earth's magnetic field, then we expect the coil output to change with depth. The coil area is the variable to look at, since variations due to changing rotation frequency are removed. In Fig. 19 the profiles seem to converge to a similar value at about 30 m. Above this depth the area seems to be influenced by the vessel.

The final two figures, 20 and 21, show examples of simultaneous profiles from deck and remote launchers aboard the Kane. Here we see clear cases of the convergence of the area variable below 30 m. Since the compass signal does enter the electric field channel, it is important to avoid magnetic contamination.

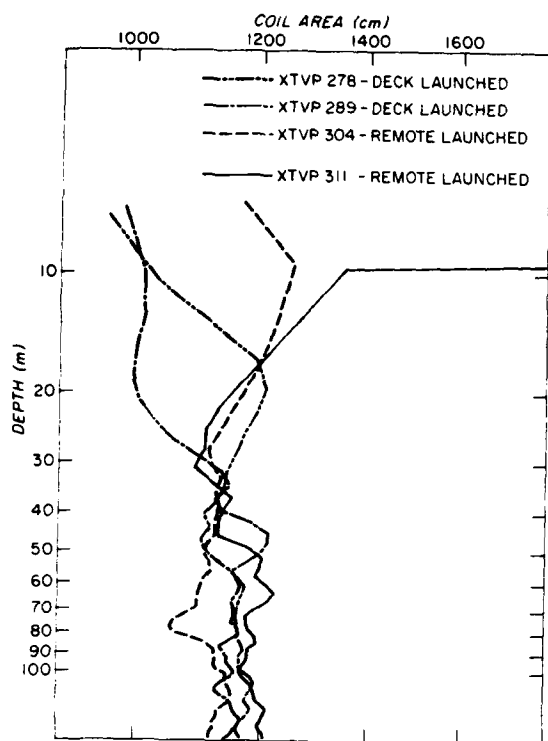


Figure 19.

Coil area profiles for variously launched probes from USNS Kane.

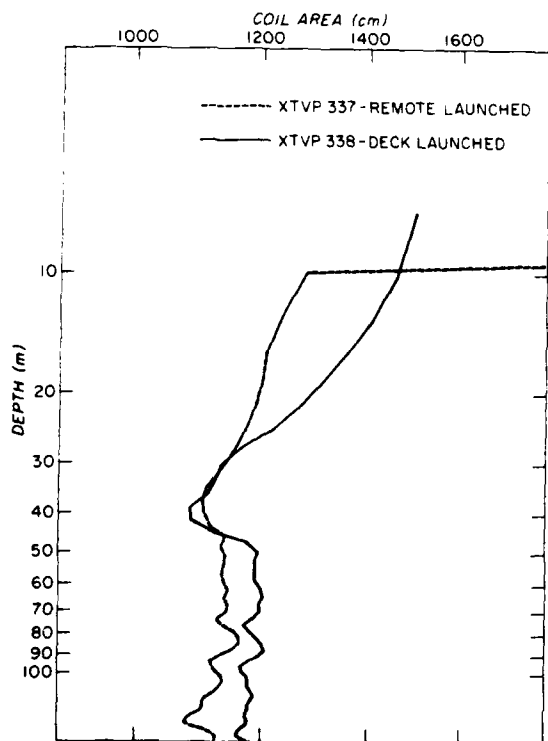


Figure 20. Simultaneous deck and remote launched profiles of coil area from USNS Kane.

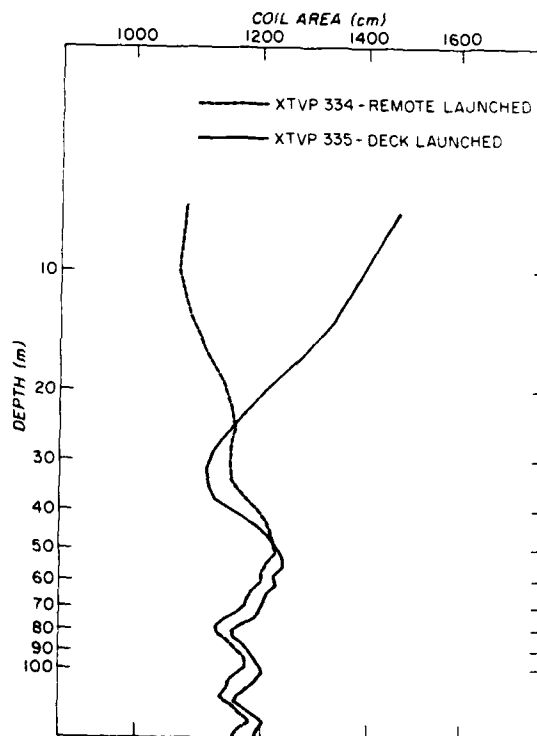


Figure 21. Simultaneous deck and remote launched profiles of coil area from USNS Kane.

The Kane profiles show a tendency for the coil area to be low around the vessel compared with that farther away. This suggests that near the ship the magnetic field is less.

On the basis of this analysis, it is recommended that probes be released 1-2 vessel lengths (100-200 m, depending on the ship) behind the vessel to reduce electric and magnetic influences to less than 1 cm/s. The analysis is subject to considerable error, since it is based on an extrapolation of near-ship observations. More profiles should be taken at distances of 1-50 m from the ships, or more detailed electric and magnetic measurements should be made. The latter does not require expenditure of XTVP probes. Also there may be a significant improvement achieved in the reduction of the electric influence if active cathodic protection (if used) is suspended during profiles. That is, p may be due to electric currents deliberately circulated to protect the propeller and shafts from corrosion. Suspension of this activity for brief periods would be beneficial to the data quality and not too detrimental to corrosion control.

The numerical calculations were carried out by John Litherland.

B. INFLUENCES OF SPATIAL AND TEMPORAL VARIATIONS OF THE GEOMAGNETIC FIELD

Spatial and temporal variations of the geomagnetic field can strongly influence the operation of the XTVP and interpretation of the measurements. The elements of the main, steady geomagnetic field determine the generation of the motionally induced electric currents. Regions of large and small geomagnetic components are shown in Fig. 22. Errors in the knowledge of these elements lead to errors in the interpretation of the measurements. An error in F_H tends to contribute an error to the north flow component, while F_z errors lead to scaling errors for both flow components. Variations of $\vec{F}$ in space and time lead to the generation of $\vec{J}^*$ electric currents.

Errors in estimating the magnetic field components arise mainly from magnetic anomalies of spatial scales smaller than detailed in the world charts (DMAHC magnetic field charts, #33 and 36). The magnitude of temporal variations is generally less than 1% of the steady field. However, these time variations generate induced electric currents which can be quite large compared with the motionally induced signals.

The main field, approximately that of a magnetic dipole aligned along the axis of rotation, has components

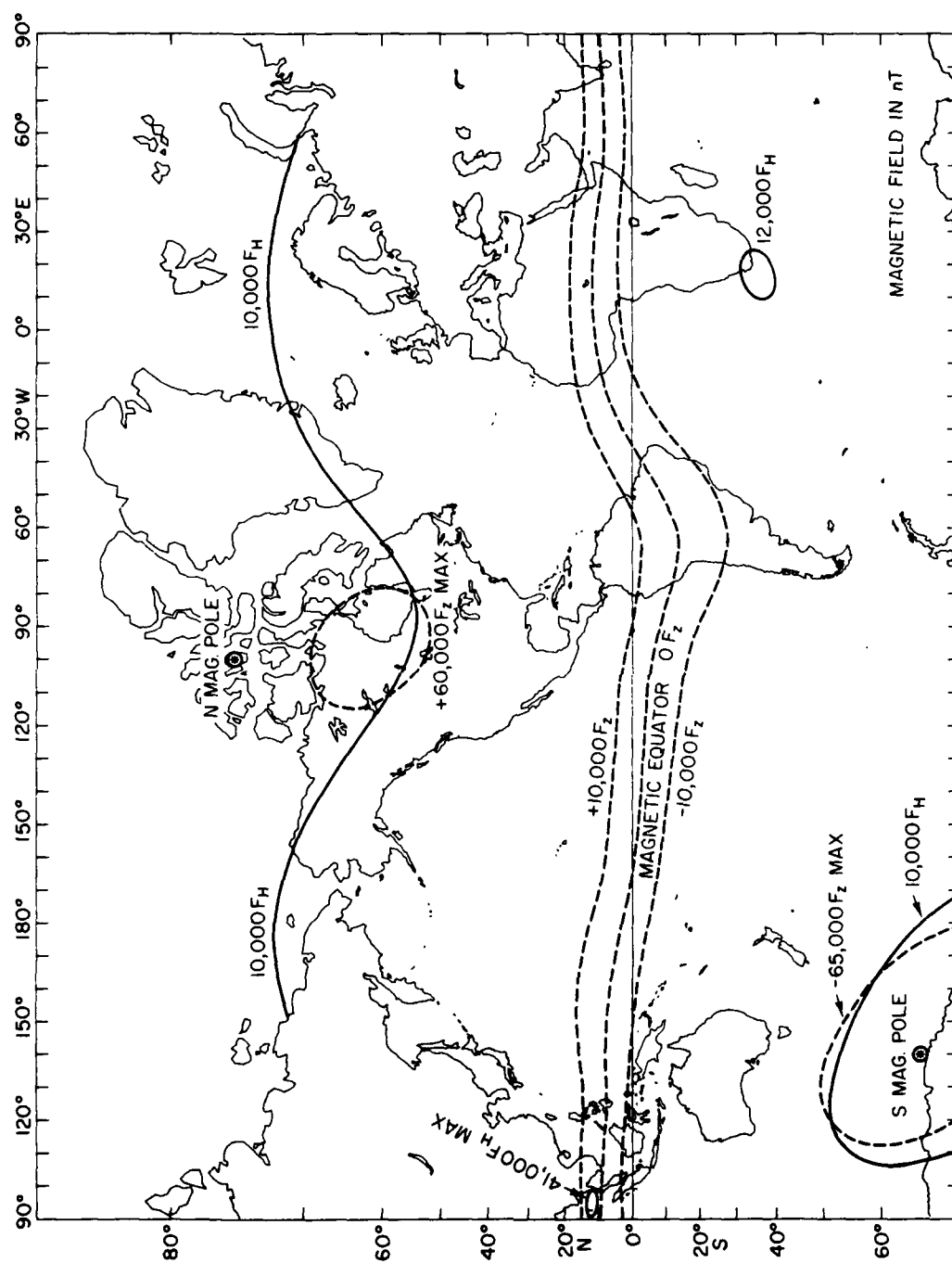


Figure 22. Locations of zones of small F_z (magnetic equator) and small F_H (magnetic poles).

$$F_H = \frac{M \cos \theta}{r^3}$$

and

$$F_Z = - \frac{2M \sin \theta}{r^3}, \quad (42)$$

where $M = 8 \times 10^{15}$ tesla-m³, θ is the latitude (positive to north) and r the geocentric radius.

The variations with depth are small: ($1 \gamma = 10^{-9}$ teslas)

$$\begin{aligned} \frac{\partial F_H}{\partial z} &\approx - 1.4 \times 10^{-11} \cos \theta \text{ tesla/m} \\ &\approx - 1.4 \cos \theta \gamma / 100 \text{ m}, \end{aligned} \quad (43)$$

$$\frac{\partial F_Z}{\partial z} \approx 2.8 \sin \theta \gamma / 100 \text{ m}.$$

Within a 5 km deep ocean, the percentage changes to F_H and F_Z are:

$$\frac{\Delta F_H}{F_H} \approx \frac{\Delta F_Z}{F_Z} \approx - 0.25\%. \quad (44)$$

The horizontal variations are

$$\begin{aligned} \frac{1}{r} \frac{\partial F_H}{\partial \theta} &= \frac{1}{2} F_Z / r \approx - 4\gamma / \text{km}, \\ \frac{1}{r} \frac{\partial F_Z}{\partial \theta} &= - 2 F_H / r \approx - 8\gamma / \text{km}. \end{aligned} \quad (45)$$

An uncertainty in latitude, $\Delta\theta$, leads to

$$\frac{\Delta F_H}{F_H} = -\Delta\theta \tan\theta ,$$

(46)

$$\frac{\Delta F_Z}{F_Z} = \Delta\theta \cot\theta .$$

At mid-latitudes ($\theta \approx 40^\circ$), the errors are ~ 1 -2% per degree of latitude. The world charts (#33 and 36) are contoured every 1000 γ for F_H and 2000 γ for F_Z , and can be scaled to at least 100 γ . If the charts were accurate to 100 γ , then $2F_H/F_H \approx 0.5\%$ and $\Delta F_Z/F_Z \approx 0.25\%$. However, it is known that the world chart is not accurate to this extent everywhere.

Small-scale magnetic anomalies exist over many topographic features such as seamounts, islands and submarine ridges. For instance, a fine-scale aeromagnetic survey of Plantagenet Bank, 25 n.mi. SW of Bermuda (Young and Kantis, 1964), reveals that the undisturbed field is 4-6% different from the world chart. Over the Bank itself, the errors reach 10-15%. Vertical and horizontal field gradients are 100 times larger than over an undisturbed area.

The magnetic field generated by the motionally induced electric currents has components no larger than 0.25% of the main geomagnetic field.

Temporal variations of the geomagnetic field generate electric fields and currents in the ocean. These magnetotelluric fields depend on the frequency and structure of the source magnetic field and on the depth and electrical conductivity of the ocean crust and mantle.

Magnetotelluric currents represent one of the largest sources of error in the EM profiling method. These effects are generally not independently measured or easily inferred from land-based magnetic measurements.

Cox, Filloux and Larsen (1971) and Fonarev (1968) have provided estimates of the electric fields generated by geomagnetic variations. The magnetic variations are described by Chapman and Bartels (1940). Variations having periods longer than one day generate only weak electric fields ($\ll 1 \mu\text{V/m}$). Shorter period variations are responsible for significant electric induction. The major categories for the high-frequency variations are the solar-diurnal variations, bay-like disturbances, magnetic storms and short-period variations.

Solar-diurnal variations are always present, even on magnetically quiet days. These variations result in electric fields of the order of $3 \times 10^{-2} \mu\text{V/m}/\gamma$ in the open ocean. The maximum influence of these variations is given in Table 12 [Fonarev (1968)].

Bay-like disturbances derive their name from their appearance as bays or gulfs on magnetograms. These events provide mainly horizontal magnetic fields which decrease away from the auroral zone (70°). Frequencies from tens of minutes to a few hours are present. Bay disturbances occur 10 to 40 times per year with an amplitude of 40-100 γ . An estimate of the resulting induction can be derived for a plane wave impinging on the sea surface. Such a wave will be attenuated as it propagates into the sea due to the generation of electric currents with opposing magnetic fields. At any depth, the magnetic field is

$$\underline{B}(z) = \underline{B}_0 e^{z/\delta}, \quad (47)$$

where $\underline{B}_0$ is the surface value and δ is the skin depth. The skin depth is defined as

$$\delta = \left(\frac{2}{\mu\sigma\omega}\right)^{1/2}, \quad (48)$$

where the permeability $\mu = 4\pi \times 10^{-7}$ H/m, σ is the electrical conductivity and ω is the radian frequency of the wave.

The electric currents can be computed from Ampere's law:

$$\nabla \times \underline{B} = \mu \underline{J}. \quad (49)$$

The electric field due to the current density $\underline{J}$ is $\underline{J}/\sigma$. Hence

$$\underline{E} = \frac{\underline{B}_0}{\mu\sigma\delta} e^{z/\delta}. \quad (50)$$

Table 12. Magnetotelluric effects [after Fonarev (1968)]:
For solar-diurnal variations

<u>Latitude</u>	<u>Activity</u>	<u>B, γ</u>	<u>E, $\mu\text{V/m}$</u>	<u>V, cm/s</u>
<30°	Quiet	30-80	0.9-2.4	4.5-12
	Disturbed	60-100	1.8-3.0	9.0-15
30-60	Quiet	15-60	0.45-1.8	1.1-4.2
	Disturbed	25-110	0.75-3.3	1.9-8.2
>60°	Quiet	90-400	2.7-12	4.6-20
	Disturbed	50-460	1.5-14	2.5-22

For magnetic storm variations¹

<u>Latitude</u>	<u>Activity</u>	<u>B, γ</u>	<u>E, $\mu\text{V/m}$</u>	<u>V, cm/s</u>
<30°	Weak	0-30	0-2	0-9
	Moderate	15-60	1-4	4-18
	Strong	30-90	2-5	9-26
30-60	Weak	40-120	2-7	6-17
	Moderate	70-300	4-16	10-44
	Strong	150-700	9-41	22-103
>60°	Weak	70-600	4-32	7-60
	Moderate	150-900	9-52	15-88
	Strong	900-1500	52-88	88-150

¹For water depth of 5 km and $\sigma = 2.7 \text{ S/m}$.

This expression is appropriate for an infinitely deep ocean or when $\delta < H$. The latter condition occurs for wave periods of 5 min or less. For longer periods, a more appropriate expression is:

$$E(\mu\text{V/m}) = \frac{\sqrt{5\rho_a} B(\gamma)}{\sqrt{T}}, \quad (51)$$

where ρ_a is the apparent resistivity (combination of ocean and mantle resistivities) in ohm-m and T is the wave period in seconds. According to Poehls and von Herzen (1976), ρ_a in the NW Atlantic is about 20 ohm-m. Hence,

$$E \sim \frac{10 B(\gamma)}{\sqrt{T}}. \quad (52)$$

For a bay-like disturbance of 40 γ over a period of 3 hours,

$$E = 3.8 \mu\text{V/m}, \quad (53)$$

leading to a velocity error of about 5 cm/s. Since the bay-like disturbances are of very large scale, it is possible to estimate the errors, perhaps even to correct the measurements, using land-based magnetic records.

Magnetic storms are more irregular than bay disturbances, often having rapid changes at the commencement over a few hours followed by a gradual recovery over tens of hours. The E/B ratios are the same as for the bay but the amplitude of B can be much larger, particularly in the auroral zone. According to Fonarev (1968), magnetic storms are as frequent as 20-50 times per year during years of maximum solar activity while 3-5 times fewer in years of minimum activity. The peak-to-peak variations and the expected electric induction and velocity errors are listed in Table 12.

Except for the most rapid components of magnetic storms, bays and diurnal disturbances produce little depth-dependent electric variations. That is, the energetic, long-period disturbances induce mainly depth-uniform electric currents, and these do not contribute errors to XTVP

profiles. Short-period variations (periods less than 10 minutes) are weak and contribute little induced electric field except in polar regions.

According to Fig. 16 of Cox et al. (1971), the electric field has a variance of about $0.1 (\mu\text{V/m})^2$ in the frequency band from 0.1 to 12 c/h. Thus we might expect deviations between profiles spaced several hours apart of about 0.6 cm/s due to changes in the ambient electric field. Over a small frequency interval, say, 1 to 12 c/h, the variance is about $10^{-2} (\mu\text{V/m})^2$ yielding a standard deviation of 0.2 cm/s.

C. TILT EFFECTS IN XTVP DATA

The XTVP is designed to measure electric currents present in the sea induced by the motion of seawater through the earth's magnetic field. Drever and Sanford (1980) and Sanford et al. (1978) discuss the calculation of oceanic velocities from these electrical measurements, assuming that the instrument remains vertical. Small instrumental tilts, however, are produced by vertical shear. In this report the effect of these tilts on the computed velocity profile is investigated and an algorithm to correct for these effects is developed and tested.

1. Model of Tilt Effects

The XTVP measures the electric potential between a pair of electrodes on opposite sides of a rotating cylinder falling through the ocean. The measured potential is the sum of a potential $\Delta\phi_v$ due to induced electric currents J and a potential $\Delta\phi_I$ due to the motion of the probe through the water. Both potentials are modified by the presence of the insulating probe within the conducting seawater.

The oceanic electric current density J is assumed to be entirely horizontal, due to the large aspect ratio of oceanic currents. Let

$$\underline{J}/\sigma = F_z(v\hat{x} - u\hat{y}) , \quad (54)$$

where $\hat{x}$, $\hat{y}$, $\hat{z}$ are unit vectors in an earth fixed coordinate system (Fig. 23). F_z is the vertical component of the earth's magnetic field and u, v are the components of the purely horizontal current relative to the unknown electrical offsets u^*, v^* (Sanford, 1971). This electrical current results in a potential drop

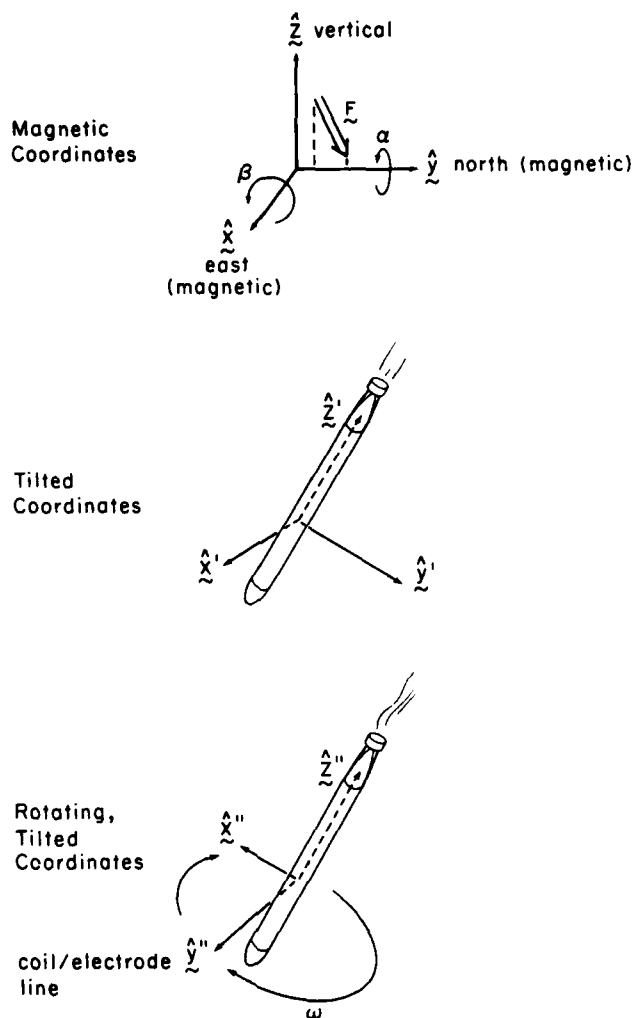


Figure 23. Coordinate systems used in the analysis. $(\hat{x}, \hat{y}, \hat{z})$ is an earth fixed system, with $\hat{y}$ pointing north (magnetic). The magnetic field has no east component, and the oceanic velocities have no z component. $(\hat{x}', \hat{y}', \hat{z}')$ is a coordinate system fixed with the probe, but not rotating, and is rotated by angles α and β with respect to $(\hat{x}, \hat{y}, \hat{z})$. $(\hat{x}'', \hat{y}'', \hat{z}'')$ is fixed with the probe and rotating with it so that $\hat{y}''$ is along the electrode/coil line. Table 13 gives the rotation matrices between these systems.

Table 13. Rotation matrices.

$$R_{\alpha}: \quad \begin{array}{l} \text{y axis rotation by } \alpha \text{ (ccw)} \\ \alpha \end{array} \quad \begin{array}{ccc} \cos \alpha & 0 & \sin \alpha \\ 0 & 1 & 0 \\ -\sin \alpha & 0 & \cos \alpha \end{array}$$

$$R_{\beta}: \quad \begin{array}{l} \text{x axis rotation by } \beta \text{ (ccw)} \\ \beta \end{array} \quad \begin{array}{ccc} 1 & 0 & 0 \\ 0 & \cos \beta & \sin \beta \\ 0 & -\sin \beta & \cos \beta \end{array}$$

$$R_{\omega}: \quad \begin{array}{l} \text{z axis rotation by } \omega \text{ (cw)} \\ \omega \end{array} \quad \begin{array}{ccc} \cos \omega t & -\sin \omega t & 0 \\ \sin \omega t & \cos \omega t & 0 \\ 0 & 0 & 1 \end{array}$$

Probe coordinates:

$$\begin{pmatrix} \hat{x}' \\ \hat{y}' \\ \hat{z}' \end{pmatrix} = R_{\beta} R_{\alpha} \begin{pmatrix} \hat{x} \\ \hat{y} \\ \hat{z} \end{pmatrix}$$

$$R_{\beta} R_{\alpha} = \begin{array}{ccc} \cos \alpha & 0 & \sin \alpha \\ -\sin \alpha \sin \beta & \cos \beta & \cos \alpha \sin \beta \\ -\sin \alpha \cos \beta & -\sin \beta & \cos \alpha \cos \beta \end{array}$$

Rotating probe coordinates:

$$\begin{pmatrix} \hat{x}'' \\ \hat{y}'' \\ \hat{z}'' \end{pmatrix} = R_{\omega} R_{\beta} R_{\alpha} \begin{pmatrix} \hat{x} \\ \hat{y} \\ \hat{z} \end{pmatrix}$$

$$R_{\omega} R_{\beta} R_{\alpha} = \begin{array}{ccc} \cos \alpha \cos \omega t & -\cos \beta \sin \omega t & \sin \alpha \cos \omega t \\ +\sin \alpha \sin \beta \sin \omega t & & -\cos \alpha \sin \beta \sin \omega t \\ \cos \alpha \sin \omega t & \cos \beta \cos \omega t & \sin \alpha \sin \omega t \\ -\sin \alpha \sin \beta \cos \omega t & & +\cos \alpha \sin \beta \cos \omega t \\ -\sin \alpha \cos \beta & -\sin \beta & \cos \alpha \cos \beta \end{array}$$

$$\Delta\phi_V = -(1+C_1)\ell\hat{y}'' \cdot \underline{\hat{x}}'' \cdot J/\sigma \quad (55)$$

across the probe electrodes, where ℓ is the electrode separation, $\hat{y}''$ is the orientation of the electrode line, and $C_1 \approx 0.9$ gives the magnification of the potential difference due to the presence of the probe. Because the electric current density must increase as the current is diverted by the probe, the voltage drop increases by the factor $1 + C_1$.

The potential $\Delta\phi_I$ induced by the probe motion relative to the water is best calculated in a nonrotating coordinate system oriented with the probe. Let $\hat{z}'$ be along the probe axis. The fixed system $\hat{x}, \hat{y}, \hat{z}$ can be transformed into the probe system $\hat{x}', \hat{y}', \hat{z}'$ by a rotation of α about $\hat{y}$ followed by an x-axis rotation of β (Table 13, Fig. 23). In this coordinate system the induced potential is given by (Sanford et al., 1978, Equation A12)

$$\begin{aligned} \Delta\phi_I = & (1+C_2)\ell\hat{y}'' \cdot (F_{y'}\hat{x}' - F_{x'}\hat{y}')W' \\ & + (1+C_3)\ell'' \cdot (U'\hat{y}' - V'\hat{x}')F_{z'} , \end{aligned} \quad (56)$$

where W' , U' , and V' are the probe velocities relative to the water in the nonrotating probe coordinate system, and $\hat{y}''$ is the orientation of the electrode line. Motion of the probe relative to the surrounding water results in two signals: induction by the relative motion of the probe itself and by the perturbation flow around the probe. These two signals may nearly cancel; the estimated values of C_2 and C_3 are -0.1 and -0.8 respectively.

The east and north components of velocity are determined relative to the voltage induced in a coil (the compass coil) coaxial with the electrode line. For technical reasons, a fraction c of the coil signal is also added to the measured electrode signal. Assuming the coil to have a total area A_0 , the potential induced in the coil by the probe's rotation is

$$\Delta\phi_c = \frac{d}{dt} (\underline{\hat{F}} \cdot A_0 \underline{\hat{y}}'') = \omega A_0 \underline{\hat{F}} \cdot \underline{\hat{x}}'' , \quad (57)$$

assuming

$$\frac{d\alpha}{dt}, \frac{d\beta}{dt} \ll \omega .$$

Using the rotation operators shown in Table 13 and Eqs. (55), (56) and (57), the following expressions can be derived to lowest order in α and β :

$$\Delta\phi_v = (1+C_1)\ell F_z [u \cos\omega t - v \sin\omega t] , \quad (58)$$

$$\begin{aligned} \Delta\phi_I = & (1+C_2)\ell W' [(F_y + \beta F_z)\sin\omega t - \alpha F_z \cos\omega t] \\ & + (1+C_3)\ell(F_z - \beta F_y)[U'\cos\omega t - V'\sin\omega t] , \end{aligned} \quad (59)$$

$$\Delta\phi_c = -F_y \omega A_o \left[\left(1 + \frac{F_z}{F_y} \beta\right) \sin\omega t - \alpha \frac{F_z}{F_y} \cos\omega t \right] . \quad (60)$$

The XTVP electrode signal transmitted up the wire is

$$\Delta\phi = \Delta\phi_v + \Delta\phi_I + c\Delta\phi_c . \quad (61)$$

This is then demodulated with the coil signal to produce in-phase (north) and quadrature (east) signals. If $\alpha = \beta = U' = V' = 0$, the coil signal is proportional to $I = \sin\omega t$, and is in quadrature with $Q = \cos\omega t$. The demodulation yields

north:

$$\Delta\phi_n = \overline{I\Delta\phi} = -v(1+C_1)\ell F_z + [(1+C_2)\ell W' + c\omega A_o]F_y , \quad (62)$$

east:

$$\Delta\phi_e = \overline{Q\Delta\phi} = u(1+C_1)\ell F_z , \quad (63)$$

where the overbar denotes a time average. Equation (62) is identical to Eq. (4) of Drever and Sanford (1980). If W' is known, the oceanic velocities u and v can be determined.

The direction of north is defined by the phase of the coil signal. For a vertical probe, the coil signal passes through zero when the coil ($\hat{y}$) points north. If the probe is not vertical, an east-west tilt results in a phase shift of the coil signal so that this zero crossing no longer gives the same direction. The demodulation signals using (60) are now

$$I = \sin \omega t - \alpha \frac{F_z}{F_y} \cos \omega t, \quad (64)$$

$$Q = \cos \omega t + \alpha \frac{F_z}{F_y} \sin \omega t, \quad (65)$$

and the demodulated signals are

north:

$$\begin{aligned} \Delta \phi_n = & - (1+C_1) \ell F_z \left(v + \alpha \frac{F_z}{F_y} u \right) \\ & + F_y (1+\beta F_z/F_y) [(1+C_2) \ell W' - c \omega A_0] \\ & - (1+C_3) \ell F_z (1-\beta F_y/F_z) \left(V' + \alpha \frac{F_z}{F_y} U' \right), \end{aligned} \quad (66)$$

east:

$$\begin{aligned} \Delta \phi_e = & (1+C_1) \ell F_z \left[u - \alpha \frac{F_z}{F_y} v \right] \\ & + (1+C_3) \ell F_z \left(1 - \frac{\beta F_y}{F_z} \right) \left(U' - \alpha \frac{F_z}{F_y} V' \right). \end{aligned} \quad (67)$$

Equations (66) and (67) give the demodulated potential difference for a tipped probe with velocities U' , V' and W' relative to the water.

Since the probe is a stable streamlined body, it will be assumed to fall along its length, so that $U' = V' = 0$. There is no direct verification of this assumption. However, since $(1+C_3)/(1+C_1) \approx 0.1$, the measured potentials are much more sensitive to oceanic velocities (u, v) than probe velocities (U', V').

The probe tilt is seen to have two major effects. An east-west tilt ($\alpha \neq 0$) changes the measured phase of the coil signal and therefore mixes east and north contributions. This is seen in the first and last terms of (66) and (67). If α is small, this effect is small. A north-south tilt changes the magnitude of the magnetic field parallel to the probe (F_z'), leading to a change in both the coil and W' induced signals. This can be seen in the second term of (66).

The effect of these tilts is seen in a different way if the calculation is done entirely in the fixed coordinate frame. Suppose the probe is falling with velocity components U, V and W in a stationary ocean (i.e., $J = 0$); the induced potential is given by

$$\Delta\phi_I = [F_y \hat{W}\hat{x} + F_z (U\hat{y} - V\hat{x})] \cdot \hat{y}'' , \quad (68)$$

where we take $C_1 = C_2 = C_3 = 0$ for simplicity. Since the probe is tilted and falling along its length, $U = \alpha W$ and $V = \beta W$. Neglecting, for the moment, the small phase shift caused by α ,

$$\hat{y}'' = \hat{x} \sin\omega t + \hat{y} \cos\omega t , \quad (69)$$

and the measured signals are

north:

$$\Delta\phi_n = \beta W F_z + W F_y = F_y (1 + \beta F_z/F_y) W , \quad (70)$$

east:

$$\Delta\phi_e = -\alpha W F_z . \quad (71)$$

The tilt causes the probe to move horizontally relative to the water; the probe measures an induced potential resulting from this motion. The resulting in-phase signal βW_F_z in (70) is clearly present in the second term of (66). The corresponding quadrature signal $-\alpha W_F_z$, however, is not present in (67). It is canceled by the east-west tip term neglected in (70) and (71). As discussed above, an east-west tip α results in a phase shift in the coil signal. This mixes the east and north potentials. The north potential is dominated not by the north velocity potential, but by induced potential due to W . The primary effect of the coil phase shift is thus to mix some of this W induced potential into the east potential. The additional east potential is of magnitude αW_F_z and exactly cancels the α induced potential in (71). Switching to probe coordinates, this clearly must be true, since the signal induced by W' is in phase with the coil, and cannot appear in the east signal. Thus, except for the small amount of east-north mixing, there is no effect of tilt in the east velocity component, to first order, if the probe falls along its length.

2. Processing Changes

The present XTVP processing computes a north velocity $\hat{v}$ using

$$\hat{v} = - [\Delta\phi_n - (1+C_2)2F_y W_e - \alpha \Delta\phi_c] / (1+C_1)2F_z, \quad (72)$$

where W_e is the estimated fall rate and $\Delta\phi_c$ is calculated from the probe rotation rate. Using (60), (64) and (66) with $U' = V' = 0$, the computed velocity will be

$$\hat{v} = (v + \alpha \frac{F_z}{F_y} u) + \frac{F_y}{F_z} \frac{(1+C_2)}{(1+C_1)} (W_e - W') - \beta \frac{(1+C_2)}{(1+C_1)} W'. \quad (73)$$

The computed north velocity contains three errors: a mixing of u with v due to east-west tip (α), an error due to the incorrect estimation of W_e , and an error due to north-south tilt (β). Since $W' \approx 450 \text{ cm/s} \gg u$, the last term is dominant. A north-south tip of 1° will lead to an error of 4 cm/s.

It is possible to correct for the β tilt. Using (60), the magnitude of the coil signal is

$$\Delta\phi_C = \omega F_Y A_O \left(1 + \frac{F_Z}{F_Y} \beta\right) . \quad (74)$$

The effective area of the coil is

$$A = \frac{\Delta\phi_C}{\omega F_Y} = A_O \left(1 + \frac{F_Z}{F_Y} \beta\right) , \quad (75)$$

which to first order in α and β is a function only of the north-south tilt. The third term in (73) can be estimated using

$$-\beta \frac{(1 + C_2)}{(1 + C_1)} W' \approx - \left(\frac{A}{A_O} - 1\right) \frac{F_Y}{F_Z} \frac{(1 + C_2)}{(1 + C_1)} W_e , \quad (76)$$

and removed from the estimate of v using

$$\hat{v} = -[\Delta\phi_n - \frac{A}{A_O} (1 + C_2) F_Y W_e - c\Delta\phi_C] / (1 + C_1) F_Z . \quad (77)$$

In practice, A_O is estimated from the vertical mean of A , since the fluctuations in A occur on a relatively short vertical scale.

3. Comparison of Tilt-Corrected and Uncorrected Profiles

Figure 24 shows a typical XTVP profile of east and north velocity and area as defined by (75). Interpreting the area fluctuations as tilt fluctuations, the probe is seen to tilt only a few degrees, north-south. These small tilts are sufficient, however, to significantly affect the computed north velocity. Notice the difference between the velocity computed using (72) (light line) and (77) (heavy line, tilt corrected). The north velocity is most affected on the 10-50 m scale, where the area, or tilt, fluctuations are concentrated. Note that the corrected profile shows less correlation with the area than the uncorrected profile, and that the tilt correction primarily affects the amplitude, not the phase, of the computed profile.

The effect of the tilt correction on different vertical scales is more clearly seen in Fig. 25. The average autospectra of east and north

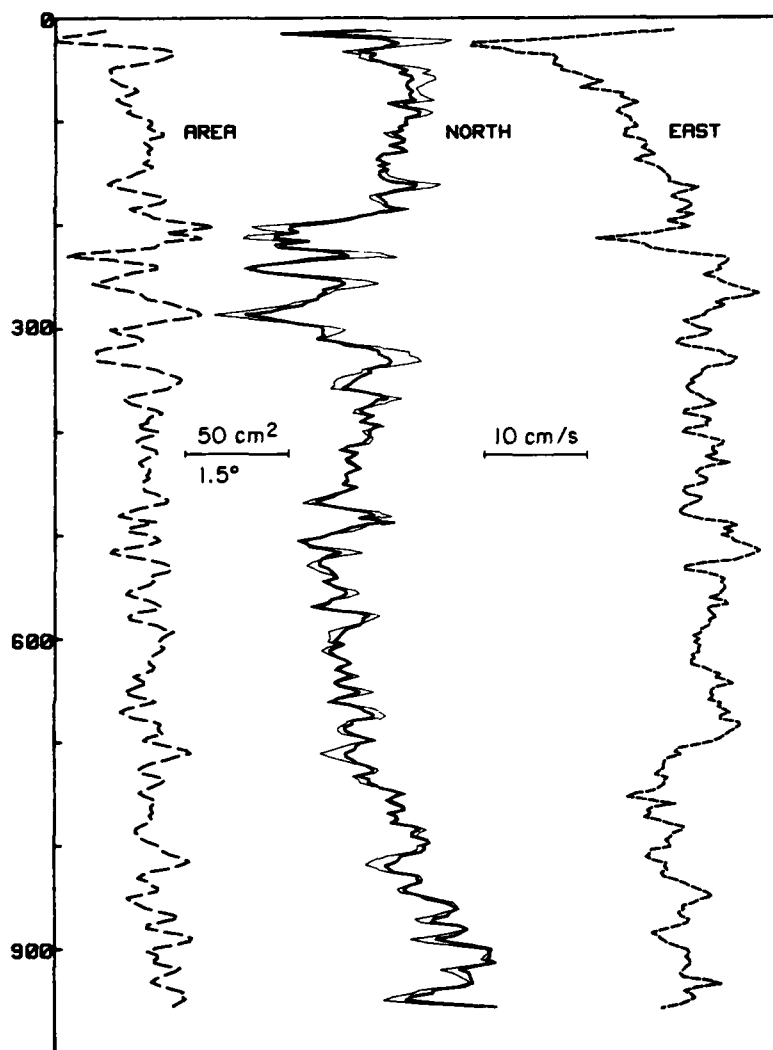


Figure 24. A low noise XTVP profile (AUTC 176) of east and north relative velocity, and effective coil area (75). North is computed both by (72) (uncorrected, light line) and by (77) (corrected, heavy line). Area is also interpreted as north-south tilt.

from 64 XTVP profiles are shown with the north velocity computed using both (72) (light line) and (77) (heavy line). The uncorrected data show more energy in north than east at scales smaller than 300 m, while the tilt corrected data show the same energy in east and north.

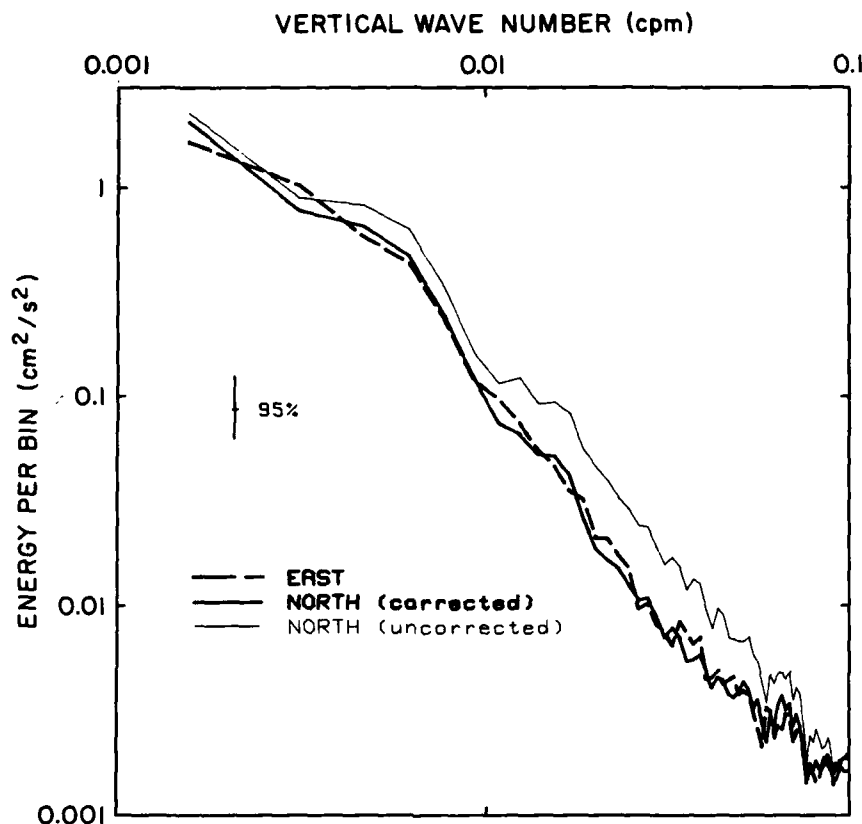


Figure 25. Average autospectra from 64 XTVP profiles taken during the USNS Kane cruise. Both tilt-corrected by (77) and uncorrected by (72) north spectra are shown. The 95% confidence interval was computed using 64 EDOF. The wavenumber bin is $1/640$ cpm.

4. Comparison with Other Measurements

The differences between the corrected and uncorrected profiles occur primarily on vertical scales where internal wave fluctuations are dominant. Current meter measurements in the open ocean usually show an isotropic internal wave field with the same amount of energy in east and north (Wunsch, 1976). The corrected XTVP profiles, which show equal energy in east and north, agree with these current meter data, while the uncorrected data profiles do not.

Simultaneous velocity profiles using two different profilers are an excellent test of both instruments. Two such comparisons are discussed below, an XTVP comparison with TOPS (Hayes, 1981; data courtesy of Dr. S. Hayes NOAA/PMEL), a profiler expected to be most accurate at 1-50 m scales, and a comparison with acoustically tracked floats (Wenstrand, 1979; data courtesy of Dr. D. Wenstrand APL/JHU), which are expected to be most accurate at scales greater than 50 m.

Figure 26 compares the data obtained from nearly simultaneous drops of an XTVP and TOPS, a free-fall velocity profiler that measures its own velocity, relative to the ocean, using a nose mounted acoustic current meter. A model of the body dynamics is used to compute the large scale velocity profile from these measurements. Figure 26 compares the auto-spectra from the uncorrected XTVP data and TOPS. The east spectra are

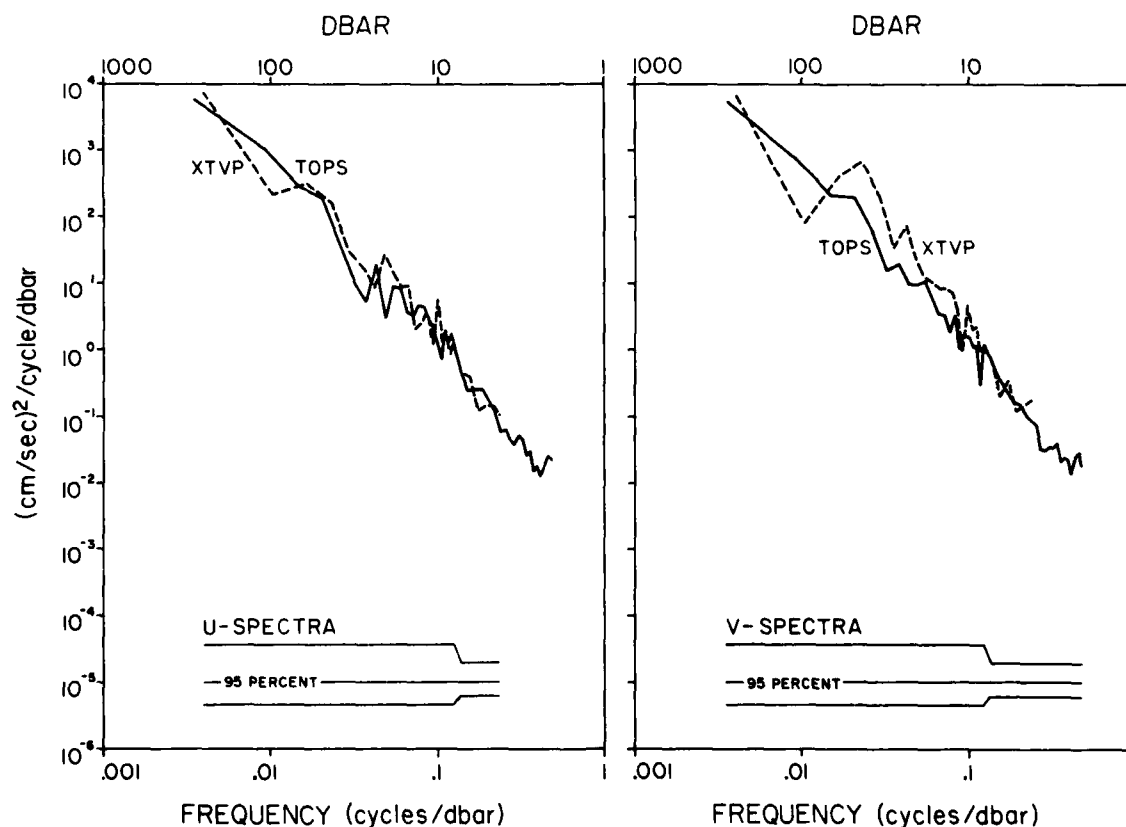


Figure 26. Autospectra from TOPS/XTVP intercomparison. XTVP data are not tilt corrected. (Figure courtesy Dr. S. Hayes, NOAA/PMEL)

quite similar. The north spectra, however, show more energy in the XTVP profile at scales smaller than 100 m, just as in Fig. 25. This again suggests that the XTVP north velocity must be corrected for north-south tilt. Figure 27 compares the TOPS and XTVP profiles. If a slowly increasing depth offset in one of the profiles is recognized, the correspondence between the two profiles, especially on a feature for feature basis, is excellent, even with the uncorrected XTVP data.

Figure 28 shows a comparison between simultaneous XTVP and acoustically tracked dropsonde data. Sanford et al. (1981) discuss this intercomparison in more detail. Figure 28 compares a typical acoustic profile with an exceptionally quiet (for this data set) XTVP, processed both by (72) (uncorrected) and (77) (corrected). All three profiles have zero vertical mean; no other adjustments have been made. The correspondence between the acoustic and the corrected XTVP profiles is excellent. The uncorrected XTVP north profile fits the acoustic profile much less accurately than the corrected profile.

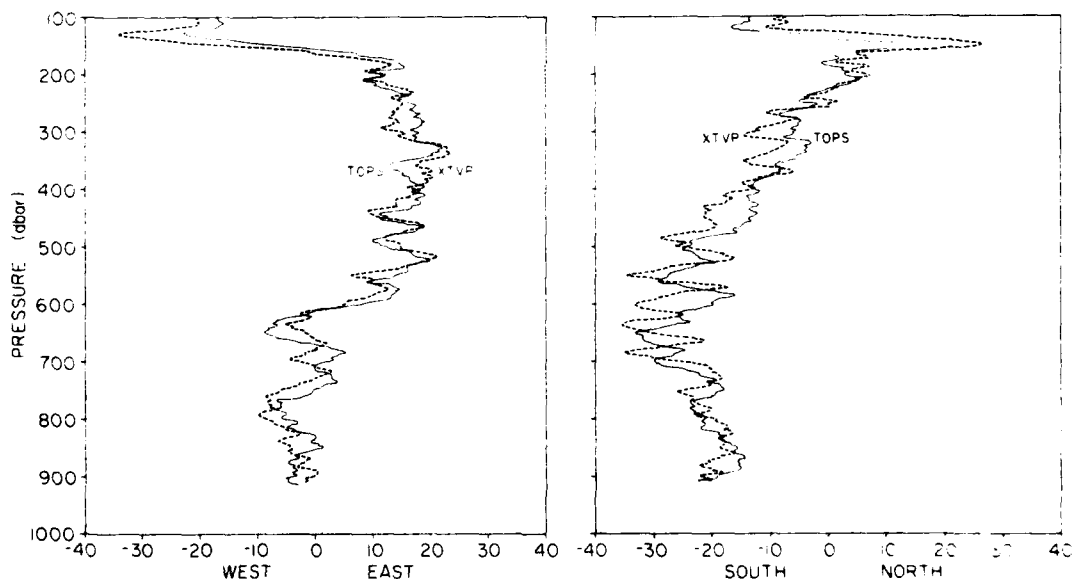


Figure 27. Velocity profiles from TOPS/XTVP intercomparison.
(Figure courtesy of Dr. S. Hayes NOAA/PMEL)

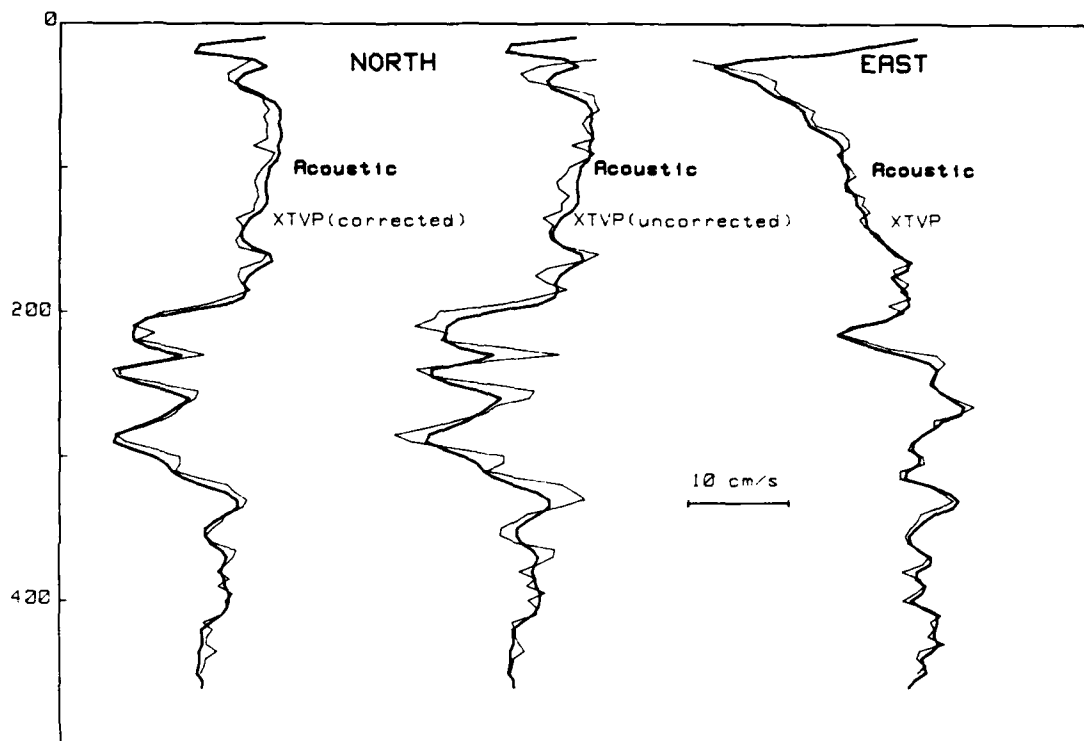


Figure 28. Comparison of nearly simultaneous XTVP (176) and acoustic tracked float (#7) velocity profiles. Both tilt-corrected by (77) and uncorrected (72) north XTVP profiles are shown. All profiles have zero vertical mean; otherwise not adjusted.

5. XTVP Error Analysis

The results of the acoustic dropsonde/XTVP intercomparison will be used to estimate the errors in the XTVP measurement. Each intercomparison set consists of an acoustic up and down profile, and several XTVP profiles taken during the acoustic profile. Three intercomparison sets are used below. In addition, simultaneous acoustic profiles using two different floats were taken.

Table 14 lists the rms differences between the various profiles averaged over all intercomparisons. Each profile is divided into two, 100-m sections (150-250 m, 250-350 m) and each pair of profiles is shifted vertically up to ± 8 m so that a maximum correlation occurs. This allows for some depth error in the XTVP.

Table 14. The rms difference between adjusted profiles (cm/s).

	<u>East</u>	<u>North</u>	
Simultaneous acoustic profiles ¹	0.77	0.61	
Acoustic up/down pairs ²	1.23	1.48	
		<u>Tilt Corrected</u>	<u>Uncorrected</u>
		<u>North</u>	<u>North</u>
XTVP nearly simultaneous ³	1.33	1.65	1.73
XTVP pairs within intercomparison ⁴	1.33	1.55	1.78
XTVP/acoustic pairs ⁵	1.19	1.38	2.06

¹ AUTECH profiles 8 and 9, 10 and 11, down profiles only.
Time differences less than 5 minutes.

² AUTECH profiles 8, 9, 10, 11.

³ All next neighbor pairs in sets (160-163), (165-169).
Time differences less than 10 minutes.

⁴ All pairs in sets (160-163), (165-169), (176, 179)

⁵ All XTVP/acoustic pairs in sets (#4, 160-163), (#5, 165-169),
(#7, 176, 179), where #4, #5, and #7 are AUTECH acoustic profiles.

For either acoustic velocity component A, let

$$A = O_A + \epsilon_A, \quad (78)$$

where O_A is the oceanic velocity field measured by a noiseless acoustic profiler and ϵ_A is a random error. From simultaneous profiles, ϵ_A can be estimated with

$$\overline{(A_1 - A_2)^2} = 2\epsilon_A^2. \quad (79)$$

Using the statistics shown in Table 14, $\epsilon_A = 0.6$ to 0.7 cm/s. The difference between the up and down acoustic profiles can be used to estimate the change in the oceanic velocity field during the profile:

$$\overline{(A_U - A_D)^2} = \overline{(O_{AU} - O_{AD})^2} + 2\epsilon_A^2. \quad (80)$$

A value of 0.5 cm/s is estimated.

Similarly, if either XTVP velocity component is given by

$$X = O_X + \epsilon_X, \quad (81)$$

simultaneous XTVP profiles can be used to estimate ϵ_X ,

$$\overline{(X_i - X_{i+1})^2} = 2\epsilon_X^2, \quad (82)$$

and the entire set of XTVP intercomparison profiles gives an estimate of the oceanic change during the experiment:

$$\overline{(X_1 - X_2)^2} = \overline{(O_{X_1} - O_{X_2})^2} + 2\epsilon_X^2. \quad (83)$$

Sufficient XTVP profiles simultaneous with the acoustic drops do not exist. The acoustic and XTVP error estimates have thus been made using data taken at different times on the same day. Table 14 shows no significant difference between the XTVP rms errors computed for nearly simultaneous profiles as in (82) or using all the profiles in each intercomparison set.

$$\overline{(O_{X_1} - O_{X_2})^2}$$

will thus be taken as zero. Some oceanic change is certainly present, but for the small number of profiles used here, it cannot be resolved.

Systematic differences may exist between the acoustic and XTVP velocity profiles. These can be computed from the XTVP/acoustic statistics:

$$\overline{(X - A)^2} = \overline{(O_X - O_A)^2} + \epsilon_X^2 + \epsilon_A^2. \quad (84)$$

Assuming that there is no temporal change in the ocean during the intercomparison, an upper limit for

$$\overline{(O_X - O_A)^2}^{1/2}$$

of 0.5 cm/s for the east or tilt corrected north is computed. Notice that the uncorrected north velocity shows a much larger systematic error of 1.6 cm/s. If some oceanic change is allowed, the calculated systematic error becomes smaller.

The XTVP errors are summarized in Table 15. The systematic velocity errors are significantly less than 1 cm/s, and the random velocity errors are about 1 cm/s. The XTVP's used in this intercomparison were early models, and showed a considerably higher noise level than more recently manufactured probes. The value of ϵ_X computed here certainly overestimates the random noise in more recent probes, probably by a factor of 2 or more.

6. Conclusions

The above analysis clearly shows the significance of small north-south tilts in affecting the measured XTVP north velocities. The velocity errors due to these tilts can be removed if the XTVP is assumed to fall along its length when tilted. An analysis of the AUTECH XTVP intercomparison with acoustically tracked floats shows that the tilt errors can be removed and an accurate velocity profile constructed.

This analysis reveals systematic differences of approximately 0.5 cm/s rms between the acoustic and XTVP profiles. The XTVP random error is estimated at 1 cm/s rms for this set of probes. The more recently manufactured probes have less random error.

Table 15. Error analysis results (cm/s).

	<u>East</u>	<u>North</u>
Acoustic random error ϵ_A	0.54	0.43
Acoustically measured oceanic change during up/down profiles		
$\frac{(O_{AU} - O_{AD})^2}{2}^{1/2}$	0.45	0.47
	<u>East</u>	<u>North</u> <u>Tilt Corrected</u> <u>Uncorrected</u>
XTVP random error ϵ_X	0.94	1.1 1.25
XTVP/acoustic systematic error		
$\frac{(O_X - O_A)^2}{2}^{1/2}$ upper bound	0.49	0.51 1.58

D. Surface Wave Interference

Surface waves produce strong surface enhanced velocities and electric currents. Typical particle velocities are about 100 cm/s, a large value compared with typical low frequency flows. Moreover, since the frequency is large, about 1 s^{-1} , the probe will see a time varying signal as it falls. The wave signal will appear as a vertical shear of wavelength equal to the probe's fall speed times the wave period. For a 6 s wave and a 4.5 m/s fall rate, the wavelength is 27 m.

The vertical attenuation of a surface wave depends on its horizontal wavenumber (k) which is ω^2/g , where ω is its frequency and g is gravity. For a 6 s period wave the wavelength is about 60 m. The velocity decreases as e^{kz} , which is $e^{-2\pi}$ or 0.002 at $z = -60 \text{ m}$. Thus, caution must be exercised in the interpretation of velocity shear in the upper 50 m under typical ocean surface wave conditions.

E. Sensitivity Analysis

The rms error of the velocity estimates U' and V' is determined numerically using randomly determined probe tilts α and β , probe gains and probe component values. The digital receiver outputs I and Q are generated given U and V using deviated gains. U' and V' are then estimated from I and Q using nominal gains and component values.

The square root of the average variance of the velocity errors for 25 U and V combinations is found for 20 pseudoprobes. This is listed in Table 16 as the U and V rms error.

Table 16.

U, V rms error as a function of gain tolerances

U, V velocity range ($\pm$ cm/s)	α, β tilt range ($\pm^\circ$)	Probe gain tolerances ($\pm^\circ$)	Probe phase tolerances ($\pm^\circ$)	V/F converter tolerances ($\pm^\circ$)	U, V rms error (cm/s)
20	1	0	0	0	0.3
20	1	1	1	1	0.4
40	0	0	0	0	
40	2	0	0	0	1.0
40	2	1	1	1	1.1

U, V rms error as a function of component tolerances

U, V velocity range ($\pm$ cm/s)	α, β tilt range ($\pm^\circ$)	Resistor tolerances ($\pm\%$)	Resistor tolerances ($\pm\%$)	V/F converter tolerances ($\pm^\circ$)	U, V rms error (cm/s)
20	1	0.1	10	1	0.3
20	1	1	10	1	0.4
20	1	1	10	5	0.5
40	2	0.1	10	1	1.1
40	2	1	10	1	1.1
40	2	1	10	5	1.3
40	2	1	10	10	2.0
40	2	5	20	10	2.1

Typical ranges of U, V and tilt were used. The rms error scales linearly with U, V ranges and also increases with tilt. As the velocity range increases one would expect larger tilts and thus a more than proportional increase in error. Even with a perfectly known probe calibration, one should expect a 1.1 cm/s rms error over ± 40 cm/s range with $\pm 2^\circ$ tilts.

Present resistor tolerances are 0.1%, but 1% would be sufficient (except for common mode rejection). The voltage to frequency (V/F) converters should be within 5% for less than 1.5 cm/s rms error.

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APPENDIX A
Program Listings and Sample Runs

Listing of Program DXGET

DXGET accepts data from the XTVP receiver via the 16-bit parallel I/O card (HP 98032A). One single HP 9845 ENTER statement is used with an integer array of 28800 words. We use DMA and NOFORMAT to ensure that no data are lost. The XTVP receiver outputs are two's complement 16-bit binary integers to match the HP 9845 integer word format. The keyboard is locked out during the ENTER to prevent loss of data.

After the HP 9845 data array is full, the array is written onto magnetic storage media for later processing by DXPRO. We elected not to collect and process simultaneously, for data integrity reasons and because the acquisition only takes 5 minutes. A more complicated program would be more prone to failure during data acquisition.

```

10 Progrev$="DXGETG"
20 ! DXGET .. JAN 16 80. GET DIGITAL RCVR XTVP DATA.
30 ! DXGETG .. SEPT 16 80. OPERATOR INPUTS THE NUMBER OF SCANS TO READ.
40 !
50 OPTION BASE 1
60 SERIAL
80 !
90 PRINT ""
100 PRINT Progrev$;" TAKES XTVP DATA FROM THE DIGITAL RECEIVER FOR THE SPECIF
IED"
110 PRINT "NUMBER OF DATA CYCLES. A DATA CYCLE IS ONE REPETITION OF EACH OF "
120 PRINT "THE TEN VARIABLES."
130 !
140 PRINT "THE USER CAN ENTER THE NUMBER OF DATA CYCLES WISHED OR CAN LEAVE"
150 PRINT "THAT PARAMETER (Ncyc) AT IT'S DEFAULT"
160 !
170 PRINT "THERE IS ONE DATA CYCLE PER XTVP REVOLUTION. "
180 !
190 PRINT "FOR REAL TIME DATA USE NCYC=2880 TO ALLOW FOR PRE-DROP TIME"
200 PRINT "FOR PLAYBACK USE NCYC=1800 IF COMPUTER IS STARTED A FEW SECONDS PR
IOR TO DROP"
210 PRINT LIN(1)
220 !
230 Ncyc=2880
240 DISP "ENTER THE NO. DATA CYCLES TO TAKE FROM THE DIG RCVR. THE DEFAULT I
S";Ncyc;
250 INPUT "",Ncyc
260 Nword=Ncyc*10
270 PRINT "THE NUMBER OF DATA CYCLES WILL BE ";Ncyc;" FOR THIS RUN"
271 PRINT "THIS WILL TAKE ";Ncyc/8;" SECONDS AT 8 HZ ROTATION FREQ."
290 !
300 INTEGER Din(32000)
310 Nword=Ncyc*10
320 REDIM Din(Nword)
330 DIM Comment$(160)
340 !
350 DISP "PUSH CONT TO START RECORDING FROM DIGITAL RECEIVER"
360 BEEP
370 PAUSE

```

```

380 !
390 OUTPUT 9;"R"                ! GET REAL TIME
400 ENTER 9;Comment$
410 !
420 DISP Comment$;" GETTING DATA FROM DIGITAL RECEIVER NOW. "
430 SYSTEM TIMEOUT OFF
440 SUSPEND INTERACTIVE
450 ENTER 11 WDMA Nword NOFORMAT;Din(*)
460 RESUME INTERACTIVE
470 SYSTEM TIMEOUT ON
480 BEEP
490 !                               STORE JUST-READ-IN DATA
500 EDIT "OUTPUT FILE NAME ?",File$
501 ASSIGN #2 TO File$,Ret
502 IF Ret<>0 THEN 510
503     DISP "FILE NAME ";File$;" EXISTS.  USE ANOTHER FILE NAME.  ";
504     GOTO 500
510 !
520 IF LEN(File$)=0 THEN 480
530 !
540 EDIT "COMMENTS ?",Comment$
550 !
560 ASSIGN #2 TO File$,Ret
570 IF Ret<>1 THEN 500
580 GOTO 640
590 !
600 DISP ERRM$;" WHILE CREATING ";File$;".  PUSH CONT USING ANOTHER DISC"
610 PAUSE
620 GOTO 500
630 !
640 ON ERROR GOTO 600
650 CREATE File$,Nword*4/256+5
660 OFF ERROR
670 !
680 ASSIGN #2 TO File$
690 READ #2,1
700 PRINT #2;Comment$
710 PRINT #2;Din(*)
720 ASSIGN #2 TO *
730 !
731 DISP Progrv$;" FINISHED"
740 BEEP
750 END

```

Program PADO, Sample Run

PADO is a program that computes the magnetic field components needed for data processing by DXPRO. The operator enters the date and position, and the program evaluates a spherical polynomial model. The program was modified by Jagit Hayre to run on the HP 9845 in BASIC. The original FORTRAN program was purchased from NOAA EDIS/NGSDC (D62), 325 Broadway, Boulder, Colorado 80303, (303) 497-6478. The model currently used is USWC75, but more refined models will soon be available.

The following page shows operator input and program output for 40°30'N and 150°55'W on 30 March 1981. The results for horizontal and vertical intensity in Gauss (10^{-4} tesla) are 0.2408963 and -0.3883425. Note that the vertical intensity is taken to be <0 in the northern hemisphere. This is the opposite of some conventions.

PADOCK 02.....CALCULATION OF THE EARTH'S MAGNETIC HORIZONTAL
(JUL '80) AND VERTICAL INTENSITY FOR A GIVEN DATE AND
POSITION.....

ARE THE GEODETIC OR GEOCENTRIC VALUES DESIRED FOR A GIVEN POSITION?
(GEODETIC/GEOCENTRIC)

GEODETIC

GEODETIC VALUES WILL BE CALCULATED FOR A GIVEN DATE AND POSITION
IS A LIST OF THE AVAILABLE MODELS DESIRED? (YES/NO)

YES

THERE ARE PRESENT 1 MODELS WHOSE NAMES ARE:

1 USWC75

MODEL 1 (USWC75) IS THE ONLY AVAILABLE MODEL--- USED BY DEFAULT

INPUT DATE: DAY, MONTH, YEAR

30,3,81

GIVEN DATE: 30/ 3/ 1981

WILL THE GIVEN POSITION'S LATITUDE BE NORTH OR SOUTH? (N/S)

N

WILL THE GIVEN POSITION'S LONGITUDE BE EAST OR WEST? (E/W)

W

POSITION		HORIZONTAL		VERTICAL
LATITUDE	LONGITUDE	INTENSITY		INTENSITY
DEG MIN N	DEG MIN W	(GAUSS)		(GAUSS)
INPUT POSITION: LATITUDE (DEG,MIN),		LONGITUDE (DEG,MIN)		
40,30,150,55				
40	30.00 150	55.00	.2408963	-.3883425
INPUT POSITION: LATITUDE (DEG,MIN),		LONGITUDE (DEG,MIN)		

Listing of Program PADOX

```

10  ! *****
20  ! PROGRAM PADDOCK-- CALCULATION OF THE EARTH'S MAGNETIC HORIZONTAL
30  ! AND VERTICAL INTENSITY FOR A GIVEN DATE AND POSITION
35  ! USING VARIOUS MODELS STORED IN DATA STATEMENTS
36  !
41  ! This program is a modification of a FORTRAN program of spherical
42  ! harmonic models for the earth's magnetic field, model AWC75,
43  ! from U.S. Dept. of Commerce, NOAA, NGSDC (D62), Environmental Data
44  ! Service, Boulder, Colorado, 80302.
50  !
60  !
70  ! INPUT REQUIRED FOR THIS PROGRAM IS:
80  ! 1) ARE THE GEODETIC OR GEOCENTRIC VALUES TO BE CALCULATED FOR THE
    ! GIVEN DATE AND POSITION?
90  ! 2) IS A LIST OF THE AVAILABLE MODELS DESIRED?
100 ! 3) IF THE # OF AVAILABLE MODELS<>0 THEN ENTER THE MODEL # OF THE
    ! DESIRED MODEL TO BE USED FOR THE CALCULATION
110 ! 4) ENTER THE DATE: DAY, MONTH, YEAR.
120 ! 5) WILL THE GIVEN POSITION'S LATITUDE BE NORTH OR SOUTH?
130 ! 6) WILL THE GIVEN POSITION'S LONGITUDE BE EAST OR WEST?
140 ! 7) ENTER POSITION: DEG MIN (LAT) DEG MIN (LONG)
    ! **** PROGRAM OUTPUTS MAGNETIC INTENSITIES IN GAUSS ****
150 ! 8) REPEAT STEP (7) AS DESIRED...
160 !
170 !
180 !
190 ! PADDOCK 01..... ORIGINAL FORTRAN PROGRAM
200 ! PADDOCK 02..... FORTRAN PROGRAM CONVERTED TO RUN ON THE HP 9845B
210 ! BY J. HAYRE , JULY 1980
220 !
230 ! PRINT "PADDOCK 02.....CALCULATION OF THE EARTH'S MAGNETIC HORIZO
    ! NTAL "
240 ! PRINT " (JUL '80) AND VERTICAL INTENSITY FOR A GIVEN DATE AN
    ! D"
250 ! PRINT " POSITION....."
260 ! PRINT LIN(1)
270 ! *****

```

```

*
280 !
290 !
300 !
310 !
320 ! C THIS PROGRAM DEMONSTRATES THE USE OF FUNCTIONS NGDXYZ AND NGCXYZ
330 ! C TO COMPUTE VALUES OF THE GEOMAGNETIC ELEMENTS, AS DEFINED BY A
340 ! C SPECIFIED MODEL OF SPHERICAL HARMONIC COEFFICIENTS, FOR A GIVEN
350 ! C TIME AND FOR A GIVEN GEODETIC OR GEOCENTRIC POSITION.
360 ! C THE SRC'S OF THE AVAILABLE MODELS ARE CONTAINED IN DATA
      STATEMENTS IN FUNCTION NGDXYZ.

370 ! C
380 ! C SAMPLE CALLS
390 ! C
400 ! C      N = NGDXYZ( YEAR, GDLAT, ELONG, GDALT, MODEL, ENTRY )
410 ! C
420 ! C      YEAR.....THE DATE IN YEARS
430 ! C      GDLAT.....GEODETIC NORTH LATITUDE, IN DEGREES
440 ! C      ELONG.....EAST LONGITUDE, IN DEGREES
450 ! C      GDALT.....ALTITUDE ABOVE THE GEOID, IN KILOMETERS
460 ! C      MODEL.....ORDINAL OF MODEL THAT IS TO BE USED
470 ! C      ENTRY.....=0 FOR SIMPLE CALL TO NGDXYZ ( NO ENTRY PT )
480 ! C WHEN THE ABOVE ENTRY IS USED, ALL VALUES ARE REFERENCED TO THE
490 ! C INTERNATIONAL ELLIPSOID OF 1961. THIS IS THE ENTRY THAT WOULD
500 ! C NORMALLY BE USED.
510 ! C
520 ! C      N = NGDXYZ( YEAR, GCLAT, ELONG, GCALT, MODEL, ENTRY )
530 ! C
540 ! C      GCLAT.....GEOCENTRIC NORTH LATITUDE, IN DEGREES
550 ! C      GCALT.....ALTITUDE ABOVE THE SPHERE OF RADIUS 6371.2KM, IN
      KM
560 ! C      ENTRY.....=1 FOR CALL TO ENTRY POINT NGCXYZ IN FUNCTION
      NGCXYZ
570 ! C
580 ! C WHEN THE ABOVE ENTRY IS USED, ALL VALUES ARE REFERENCED TO THE
590 ! C SPHERICAL EARTH WHOSE RADIUS IS 6371.2KM.
600 ! C
610 ! C RAD
620 ! C OPTION BASE 1
630 ! C COM X,Y,Z,Xdot,Ydot,Zdot,Models,Name$(20),Xmn(900),Ymn(900),Zmn(900)
      )
640 ! C
650 ! C FUNCTION NGDXYZ RETURNS THE MAGNETIC ELEMENTS X(NORTHWARD
660 ! C INTENSITY), Y(EASTWARD INTENSITY), AND Z(DOWNWARD INTENSITY),
670 ! C AND THEIR ANNUAL RATES, VIA COMMON . THE UNITS ARE
680 ! C GAMMAS (NANOTESLAS) AND GAMMAS/YEAR (NANOTESLAS/YEAR). THESE
690 ! C VALUES APPLY TO THE DATE AND POSITION USED IN THE CALL
700 ! C STATEMENT.
710 ! C
720 ! C
730 ! C DETERMINE IF GEODETIC OR GEOCENTRIC VALUES ARE DESIRED
740 ! C
750 ! C INPUT "ARE THE GEODETIC OR GEOCENTRIC VALUES DESIRED FOR A GIVEN PO
      SITION?
      (GEODETIC/GEOCENTRIC)",Geotype$
760 ! C IF (Geotype$="GEOCENTRIC") OR (Geotype$="GEODETIC") THEN 880
770 ! C BEEP
780 ! C DISP "MISPELLED DESIRED TYPE--- ",Geotype$
790 ! C GOTO 750

```

AD-A115 659

WASHINGTON UNIV SEATTLE APPLIED PHYSICS LAB

F/G 8/3

DESIGN, OPERATION AND PERFORMANCE OF AN EXPENDABLE TEMPERATURE --ETC(U)

MAY 82 T B SANFORD, R G DREVER, J H DUNLAP

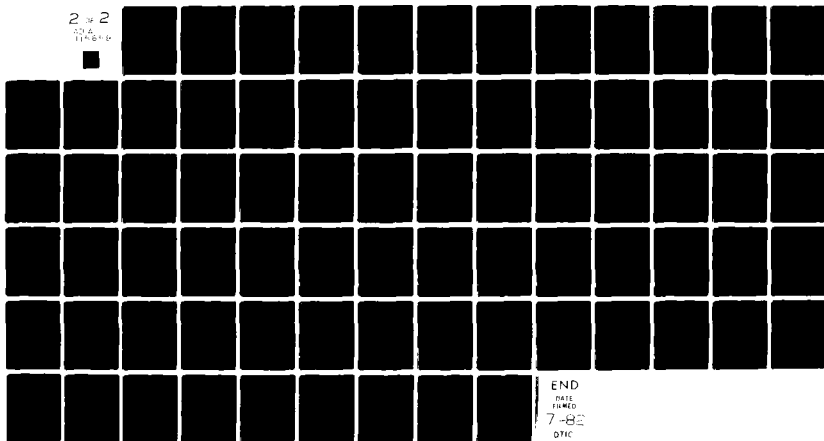
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NL

2 of 2
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END

DATE

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DTIC

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800 ! C
810 ! C FIRST WE MAKE A DUMMY CALL TO NGDXYZ. THIS FIRST CALL WILL SIMPLY
820 ! C READ THE SHC MODEL HEADER CARDS, PLACE IN MODELS THE NUMBER OF SHC
830 ! C MODELS, AND PLACE IN NAMES THE INDIVIDUAL MODEL NAMES. THIS DUMMY
840 ! C CALL IS NORMALLY UNNECESSARY, IT IS NEEDED HERE ONLY BECAUSE WE WIS
H
850 ! C TO PRINT THE NUMBER OF MODELS AND THEIR NAMES BEFORE MAKING AN ACTU
AL
860 ! C CALL TO NGDXYZ.
870 ! C
880 PRINT USING "K";Geotype$," VALUES WILL BE CALCULATED FOR A GIVEN DA
TE AND POSITION"
890 N=FNNgdxyz(1999,0,0,0,0,0)
900 INPUT "IS A LIST OF THE AVAILABLE MODELS DESIRED? (YES/NO)",Respons
e$
910 IF Response$="NO" THEN 990
920 !
930 ! OUTPUT THE LIST OF AVAILABLE MODELS
940 !
950 PRINT USING "/3(K)";"THERE ARE PRESENT ",Models," MODELS WHOSE NAME
S ARE: "
960 FOR I=1 TO Models
970 PRINT USING "1X,DD,2X,K/";I,Name$(I) ! OUTPUT AVAILABLE MODEL NAM
ES
980 NEXT I
990 Model=1
1000 IF Models<>1 THEN 1060
1010 PRINT USING "K";"MODEL 1 (<,Name$(1),>) IS THE ONLY AVAILABLE MODEL
--- USED BY DEFAULT"
1020 GOTO 1110
1030 !
1040 ! INPUT THE DESIRED MODEL NUMBER
1050 !
1060 INPUT "ENTER THE NUMBER OF THE DESIRED MODEL",Model
1070 IF (Model>1) OR (Model<=Models) THEN 1110
1080 BEEP
1090 DISP "MODEL NUMBER ",Model,"OUT OF RANGE ---- MAX MODEL NUMBER IS "
,Models
1100 GOTO 1060
1110 IF Models>1 THEN PRINT USING "/3(K)";"MODEL ",Model," (<,Name$(Mode
l),>) IS BEING USED FOR THIS RUN"
1120 Rod=.017453293 ! RAD/DEGREE CONVERSION FACTOR
1130 Rod=Rod+SIN(180.0*Rod)/180.0
1140 Rod=Rod+SIN(180.0*Rod)/180.0
1150 Rom2=2*Rod/60.0
1160 !
1170 ! C
1180 ! C
1190 ! C READ IN THE DATE AND POSITION DIRECTION
1200 !
1210 INPUT "INPUT DATE: DAY, MONTH, YEAR",Day,Month,Year
1211 IF Year<1900 THEN Year=Year+1900
1220 Date=Year+Month/12+Day/365
1230 PRINT USING "K,2(DD,K),DDDD";"GIVEN DATE: ",Day,"/ ",Month,"/ ",Ye
ar

```

```

1240      INPUT "WILL THE GIVEN POSITION'S LATITUDE BE NORTH OR SOUTH? (N/S)"
,Dirns$
1250      IF (Dirns$="N") OR (Dirns$="S") THEN 1290
1260      BEEP
1270      DISP "DIRECTION MUST BE N OR S ---- ",Dirns$," IS ILLEGAL "
1280      GOTO 1240
1290      INPUT "WILL THE GIVEN POSITION'S LONGITUDE BE EAST OR WEST? (E/W)",
Direw$
1300      IF (Direw$="E") OR (Direw$="W") THEN 1370
1310      BEEP
1320      DISP "DIRECTION MUST BE E OR W ---- ",Direw$," IS ILLEGAL "
1330      GOTO 1290
1340 !
1350 !      PRINT TABLE HEADINGS
1360 !
1370      PRINT LIN(2)
1380      PRINT "          POSITION          HORIZONTAL    VERTICAL"
1390      PRINT "  LATITUDE    LONGITUDE    INTENSITY    INTENSITY"
1400      PRINT USING "2(K,1A),K/";"DEG MIN ",Dirns$,"    DEG MIN ",Direw$,"
      (GAUSS)      (GAUSS)"
1410 !
1420 !      READ IN THE POSITION (ACTUAL LOOPING OCCURS HERE)
1430 !
1440 Input:  INPUT "INPUT POSITION:  LATITUDE (DEG,MIN),    LONGITUDE (DEG,MI
N)",Alatdeg,Alatmin,Elondeg,Elonmin
1450      Alat=Alatdeg+Alatmin/60.0
1460      Elon=Elondeg+Elonmin/60.0
1470      IF Dirns$="S" THEN Alat=-Alat
1480      IF Direw$="W" THEN Elon=-Elon
1490      Alt=0
1500      IF Geotype$="GEOCENTRIC" THEN 1640
1510 !
1520 ! C      OBTAIN VALUES FOR THE GIVEN DATE AT THE GIVEN GEODETIC POSITION.
1530 ! C
1540 !
1550      N=FNNgdxyz(Date,Alat,Elon,Alt,Model,0)
1560 !
1570 ! C      WE NOW HAVE VALUES AND RATES FOR MAGNETIC ELEMENTS X, Y, AND Z.
1580 ! C      VALUES FOR THE OTHER GEOMAGNETIC ELEMENTS, IF NEEDED, MUST BE
1590 ! C      COMPUTED.
1600 ! C
1610 ! C
1620 ! C      HORIZONTAL INTENSITY
1630 ! C
1640      H=SQR(X^2+Y^2)
1650      Hdot=(SQR((X+Xdot)^2+(Y+Ydot)^2)-SQR((X-Xdot)^2+(Y-Ydot)^2))/2
1660 ! C      HDOT = (X*XDOT + Y*YDOT)/H    H GT 1000GAMMAS
1670 ! C
1680 ! C      TOTAL INTENSITY
1690 ! C
1700      F=SQR(X^2+Y^2+Z^2)
1710 ! C      F = SQRT( H**2 + Z**2 )
1720      Fdot=(SQR((X+Xdot)^2+(Y+Ydot)^2+(Z+Zdot)^2)-SQR((X-Xdot)^2+(Y-Ydot)
^2+(Z-Zdot)^2))/2
1730 ! C      FDOT = (X*XDOT + Y*YDOT + Z*ZDOT)/F OR
1740 ! C      FDOT = (H*HDOT + Z*ZDOT)/F    F GT 1000GAMMAS

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```

1750 ! C
1760 ! C      DECLINATION
1770 ! C
1780      D=FNAtan2(Y,X)/Rod
1790      Ddot=(FNAtan2(Y+Ydot,X+Xdot)-FNAtan2(Y-Ydot,X-Xdot))/Rom2
1800 ! C
1810 ! C      INCLINATION
1820 ! C
1830      Dip=FNAtan2(Z,H)/Rod
1840      Dipdot=(FNAtan2(Z+Zdot,H+Hdot)-FNAtan2(Z-Zdot,H-Hdot))/Rom2
1850 ! C
1860 ! C
1870 ! C
1880      IF Geotype$="GEODETIC" THEN M9
1890 ! C
1900 ! C
1910 ! C      OBTAIN GEOCENTRIC VALUES FOR THE GIVEN GEOCENTRIC POSITION
1920 ! C
1930      N=FNNGdxyz(Date,Alat,Elon,Alt,Model,1)
1940 M9:      ! CONVERT Y,Z TO GAUSS FOR PRINTING (1 GAUSS= 1E5 NANOTESLAS)
1950      Z=-Z/1E5
1960      H=H/1E5
1970      PRINT USING "2(3D,1X,3D.DD,2X,1X),2(3D.DDDDDDD,2X)";Alatdeg,Alatmin
,Elondeg,Elonmin,H,Z
1980      GOTO Input
1990      END
2000 !
2010 !
2020 DEF FNNGdxyz(Yr,Alat,Elon,Alt,Kthmod,Entry)
2030      OPTION BASE 1
2040      COM X,Y,Z,Dx,Dy,Dz,Models,Model$(20),Xmn(900),Ymn(900),Zmn(900)
2050 ! C
2060 ! C FOR THE GIVEN YEAR, GEODETIC POSITION, ALTITUDE, AND MODEL, THIS
2070 ! C FUNCTION COMPUTES THE MAGNETIC ELEMENTS X, Y, Z, XDOT, YDOT, ZDOT,
2080 ! C AND RETURNS THEM IN COMMON.
2090 ! C
2100 ! C
2110 ! C      AT THE FIRST ENTRY, THIS FUNCTION READS A DECK OF 1 TO 20 MODELS.
2120 ! C      THIS DECK IS TERMINATED BY A CARD WITH 9999 IN CC 1-4.
2130 ! C
2140 ! C      P A R A M E T E R S
2150 ! C
2160 ! C      YR.....DATE IN YEARS / 1975.0
2170 ! C      ALAT.....NORTH LATITUDE IN DEGREES / 40.0
2180 ! C      ELON.....EAST LONGITUDE, IN DEGREES / -103.0
2190 ! C      ALT.....HEIGHT ABOVE THE GEOID IN KILOMETERS / 100.0
2200 ! C      KTHMOD.....EITHER...THE ORDINAL OF THE MODEL, IE, 3 WILL
2210 ! C      CAUSE THE 3RD MODEL TO BE USED
2220      ENTRY.....=0 IMPLIES SIMPLE FUNCTION NGDXYZ CALL
2230      =1 IMPLIES ENTRY NGCXYZ CALL.
2240 ! C
2250 ! C
2260 ! C      ON RETURN, THE VALUE OF NGDXYZ WILL INDICATE WHAT ERROR, IF ANY, OC
CURRED.
2270 ! C
2280 ! C      NGDXYZ = 0.....NO ERROR
2290 ! C      = -1.....ERROR IN MODEL DATA RECORD. FATAL
2300 ! C      = -2.....ARRAY G (WHEREIN THE SHC S OF THE MODELS ARE STORED)

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IS
2310 ! C          NOT LARGE ENOUGH. (THE SIZE OF G IS GIVEN BY MAXGS).
FATAL.
2320 ! C          = -3....MODEL SPECIFIED BY KTHMOD NOT FOUND. FATAL.
2330 !
2340 ! C          = 1.....YR OUTSIDE DATE LIMITS SET BY MODEL HEADER CARD
2350 ! C          = 2.....ALT OUTSIDE HEIGHT LIMITS SET BY HEADER CARD
2360 ! C          = 3.....BOTH YR AND ALT OUTSIDE LIMITS
2370 ! C
2380 ! C
2390 ! C
2400          DIM Ijs(20,3),Max(20,3),Epoch(20),Yrmin(20),Yrmax(20),Altmax(20),Al
tmin(20),G(600)
2410 ! C          THE SIZE OF ARRAY G IS PROBABLY UNREASONABLY LARGE FOR MOST USERS.
2420 ! C          IF ITS SIZE IS CHANGED, THEN THE VALUE OF MAXGS, AS SET IN THE
2430 ! C          FIRST DATA STATEMENT, MUST ALSO BE CHANGED.
2440 ! C
2450 ! C
2460          IF Entry=1 THEN Lngcxyz      ! ENTRY NGCXYZ SIMULATION
2470 ! C          ENTRY NGCXYZ SIMULATION
2480          Ngdgc=0
2490 A1:      READ Maxgs,Models
2500          DATA      600,      0
2510          READ Maxmod,Maxxyz
2520          DATA      20,      30
2530          IF Kthmod=0 THEN A2
2540          MAT Ijs=(0)
2550          MAT Yrmax=(2000)
2560          MAT Yrmin=(0)
2570          MAT Altmax=(1.00E11)
2580          MAT Altmin=(-1.00E11)
2590          READ Nthold,Killer
2600          DATA      -1,      1
2610 !
2620 ! ***** MODEL "USWC75" *****
2630 !
2640 DATA 0,0,"USWC75", 1975.0, 12, 8, 0, 1967.0, 1980.0, -1.0, 100.0
2650 DATA 0,1,-30055.7, 0, 24.39, 0, 0,0
2660 DATA 1,1,-2017.0, 5670.5, 9.94, -10.29, 0,0
2670 DATA 0,2,-1932.0, 0, -24.85, 0, 0,0
2680 DATA 1,2, 3001.3,-2044.4, 1.19, -3.08, 0,0
2690 DATA 2,2, 1619.7, -69.2, 3.10, -10.98, 0,0
2700 DATA 0,3, 1267.1, 0, -3.74, 0, 0,0
2710 DATA 1,3,-2127.2, -343.5, -10.42, 6.68, 0,0
2720 DATA 2,3, 1259.4, 263.2, -3.41, 2.13, 0,0
2730 DATA 3,3, 818.0, -208.5, -3.70, -3.53, 0,0
2740 DATA 0,4, 953.8, 0, .46, 0, 0,0
2750 DATA 1,4, 786.1, 196.7, -1.78, 4.65, 0,0
2760 DATA 2,4, 437.8, -257.0, -3.69, .96, 0,0
2770 DATA 3,4, -412.8, 20.1, -2.06, .87, 0,0
2780 DATA 4,4, 232.3, -287.5, -1.60, -1.37, 0,0
2790 DATA 0,5, -214.2, 0, .31, 0, 0,0
2800 DATA 1,5, 357.4, 31.4, -.34, 1.45, 0,0
2810 DATA 2,5, 256.1, 150.7, .96, 2.04, 0,0
2820 DATA 3,5, -42.8, -137.4, -1.16, -1.27, 0,0
2830 DATA 4,5, -166.7, -81.9, -.37, 1.34, 0,0
2840 DATA 5,5, -58.9, 86.2, .63, 1.04, 0,0

```

2850	DATA	0,6,	41.7,	0	,-.35,	0	,0,0
2860	DATA	1,6,	64.2,	-19.9,	.09,	-.65,	0,0
2870	DATA	2,6,	18.3,	105.6,	1.75,	-.03,	0,0
2880	DATA	3,6,	-199.4,	60.8,	2.13,	-.61,	0,0
2890	DATA	4,6,	3.2,	-39.2,	-.06,	-1.01,	0,0
2900	DATA	5,6,	10.6,	1.8,	.92,	1.11,	0,0
2910	DATA	6,6,	-108.5,	14.6,	.24,	1.48,	0,0
2920	DATA	0,7,	74.3,	0	.45,	0	,0,0
2930	DATA	1,7,	-49.7,	-73.0,	.17,	-1.50,	0,0
2940	DATA	2,7,	5.4,	-27.9,	.57,	-.02,	0,0
2950	DATA	3,7,	24.8,	-5.2,	.87,	.49,	0,0
2960	DATA	4,7,	-11.8,	8.2,	.94,	.23,	0,0
2970	DATA	5,7,	-3.7,	13.9,	.02,	-.80,	0,0
2980	DATA	6,7,	15.0,	-21.0,	.13,	.17,	0,0
2990	DATA	7,7,	.3,	-9.3,	-.15,	.45,	0,0
3000	DATA	0,8,	12.4,	0	.04,	0	,0,0
3010	DATA	1,8,	8.4,	6.9,	.37,	-.22,	0,0
3020	DATA	2,8,	-3.7,	-15.4,	.14,	-.36,	0,0
3030	DATA	3,8,	-11.7,	4.8,	-.11,	-.04,	0,0
3040	DATA	4,8,	-8.5,	-17.0,	-.48,	-.28,	0,0
3050	DATA	5,8,	5.9,	11.0,	-.27,	.40,	0,0
3060	DATA	6,8,	2.9,	15.5,	.55,	-.18,	0,0
3070	DATA	7,8,	7.1,	-9.6,	-.41,	-.70,	0,0
3080	DATA	8,8,	3.1,	-19.1,	-.17,	.04,	0,0
3090	DATA	0,9,	12.5,	0	0	0	,0,0
3100	DATA	1,9,	5.2,	-17.2,	0	0	,0,0
3110	DATA	2,9,	1.5,	17.2,	0	0	,0,0
3120	DATA	3,9,	-7.4,	4.2,	0	0	,0,0
3130	DATA	4,9,	11.9,	-.1,	0	0	,0,0
3140	DATA	5,9,	2.3,	-4.9,	0	0	,0,0
3150	DATA	6,9,	-.4,	9.1,	0	0	,0,0
3160	DATA	7,9,	2.9,	12.2,	0	0	,0,0
3170	DATA	8,9,	1.6,	-2.9,	0	0	,0,0
3180	DATA	9,9,	-.8,	.8,	0	0	,0,0
3190	DATA	0,10,	-5.5,	0	0	0	,0,0
3200	DATA	1,10,	-2.0,	.2,	0	0	,0,0
3210	DATA	2,10,	2.0,	.6,	0	0	,0,0
3220	DATA	3,10,	-2.7,	-.5,	0	0	,0,0
3230	DATA	4,10,	-4.0,	4.3,	0	0	,0,0
3240	DATA	5,10,	9.1,	-4.0,	0	0	,0,0
3250	DATA	6,10,	4.2,	2.7,	0	0	,0,0
3260	DATA	7,10,	-2.2,	-2.0,	0	0	,0,0
3270	DATA	8,10,	-.8,	4.3,	0	0	,0,0
3280	DATA	9,10,	5.0,	.1,	0	0	,0,0
3290	DATA	10,10,	2.1,	-4.5,	0	0	,0,0
3300	DATA	0,11,	4.4,	0	0	0	,0,0
3310	DATA	1,11,	-3.1,	1.0,	0	0	,0,0
3320	DATA	2,11,	-2.7,	2.4,	0	0	,0,0
3330	DATA	3,11,	5.0,	-2.1,	0	0	,0,0
3340	DATA	4,11,	-.3,	2.4,	0	0	,0,0
3350	DATA	5,11,	-1.3,	3.2,	0	0	,0,0
3360	DATA	6,11,	-1.0,	1.7,	0	0	,0,0
3370	DATA	7,11,	1.0,	-.7,	0	0	,0,0
3380	DATA	8,11,	.9,	-3.0,	0	0	,0,0
3390	DATA	9,11,	-2.1,	-2.1,	0	0	,0,0
3400	DATA	10,11,	.8,	.2,	0	0	,0,0
3410	DATA	11,11,	-.5,	-.1,	0	0	,0,0

```

3420 DATA 0,12,    -.7,    0,    0,    0,    0,0
3430 DATA 1,12,    0.0,    1.3,    0,    0,    0,0
3440 DATA 2,12,    1.6,    -1.8,    0,    0,    0,0
3450 DATA 3,12,    .4,    .9,    0,    0,    0,0
3460 DATA 4,12,    -1.5,    .1,    0,    0,    0,0
3470 DATA 5,12,    -1.2,    -1.8,    0,    0,    0,0
3480 DATA 6,12,    -.4,    1.4,    0,    0,    0,0
3490 DATA 7,12,    -3.6,    -1.1,    0,    0,    0,0
3500 DATA 8,12,    .6,    .1,    0,    0,    0,0
3510 DATA 9,12,    .8,    1.9,    0,    0,    0,0
3520 DATA 10,12,    -.3,    -3.3,    0,    0,    0,0
3530 DATA 11,12,    1.3,    .6,    0,    0,    0,0
3540 DATA 12,12,    .7,    1.5,    0,    0,    0,0

```

3550 !

3560 ! *****

*

3570 !

3580 !

3590 ! ***** TERMINATION DATA HEADER CARD *****

*

3600 DATA 99,99,"END" , 0 , 0, 0, 0, 0, 0, 0

3610 ! *****

3620 !

3630 !

3640 Ngdxyz=0

3650 IF Models>0 THEN A10

3660 Ijnext=0

3670 A2: I=Models+1

3680 IF I>Maxmod THEN A8

3690 ! C

3700 ! C READ MODEL HEADER CARD

3710 ! C

3720 IF I=1 THEN RESTORE 2640 ! SELECT THE DATA FOR THE Ith MODEL

3730 IF I=2 THEN RESTORE 3600 ! TERMINATION DATA HEADER CARD IS

REQUIRED

3740 ! C READ 102, M, N, MODEL(I), EPOCH(I), (MAX(I,JJ), JJ = 1, 3),

3750 READ M,N,Model\$(I),Epoch(I),Max(I,1),Max(I,2),Max(I,3),Yrmni,Yrmxi,

Altzni,Altzni

3760 IF M=99 THEN A9 ! CHECK FOR TERMINATION MODEL HEADER CARD

3770 IF Kthmod<>0 THEN A3

3780 ! THIS LOOP SIMPLY COUNTS THE NUMBER OF MODELS AVAILABLE (BY THE DUMM
Y CALL TO NGDXYZ FROM THE MAIN PROGRAM)

3790 Models=Models+1

3800 GOTO A2

3810 A3: IF (M<>0) OR (N<>0) THEN A81

3820 IF Altzni<>0 THEN Altzni(I)=Altzni

3830 IF Altzni<>0 THEN Altzni(I)=Altzni

3840 IF Yrmni<>0 THEN Yrmni(I)=Yrmni

3850 IF Yrmxi<>0 THEN Yrmxi(I)=Yrmxi

3860 FOR J=1 TO 3

3870 IF Max(I,J)=0 THEN A4

3880 Max(I,J)=Max(I,J)+1

3890 Ijs(I,J)=Ijnext

3900 Ijnext=Ijnext+Max(I,J)^2

3910 NEXT J

3920 A4: IF Ijnext>=Maxgs THEN A82

3930 Models=I

```

3940 !      CALCULATE THE NUMBER OF DATA STATEMENTS TO BE READ FOR THE DESIRED
MODEL
3950      Ncards=Max(I,1)*(Max(I,1)+1)/2
3960      Maxg=Max(I,1)
3970      Maxdg=Max(I,2)
3980      Maxd2g=Max(I,3)
3990      Ij10=Ijs(I,1)
4000      Ij20=Ijs(I,2)
4010      Ij30=Ijs(I,3)
4020      Ij1=Ij10+1
4030      FOR Ij=Ij1 TO Ijnext
4040      G(Ij)=0
4050      NEXT Ij
4060      FOR Nc=2 TO Ncards
4070 ! C
4080 ! C      READ MODEL DATA CARD
4090 ! C
4100 ! C      READ 104,  M, N, GMN, HMN, DGMN, DHMN, D2GMN, D2HMN, MODEL C
4110      READ M,N,Gmn,Hmn,Dgmn,Dhmn,D2gmn,D2hmn
4120      Ij1=Ij10+N*Maxg+M+1
4130      Ij2=Ij20+N*Maxdg+M+1
4140      Ij3=Ij30+N*Maxd2g+M+1
4150      G(Ij1)=Gmn
4160      IF Dgmn<>0 THEN G(Ij2)=Dgmn
4170      IF D2gmn<>0 THEN G(Ij3)=D2gmn
4180      IF M=0 THEN A6
4190      Ji1=Ij10+(M-1)*Maxg+N+1
4200      Ji2=Ij20+(M-1)*Maxdg+N+1
4210      Ji3=Ij30+(M-1)*Maxd2g+N+1
4220      G(Ji1)=Hmn
4230      IF Dhmn<>0 THEN G(Ji2)=Dhmn
4240      IF D2hmn<>0 THEN G(Ji3)=D2hmn
4250 A6:      NEXT Nc
4260      CALL Smigau(G(*),Ij10+1,Maxg,Maxg)
4270      IF Maxdg<>0 THEN CALL Smigau(G(*),Ij20+1,Maxdg,Maxdg)
4280      IF Maxd2g<>0 THEN CALL Smigau(G(*),Ij30+1,Maxd2g,Maxd2g)
4290      GOTO A2
4300 A8:      IF M<>99 THEN A81
4310 A9:      IF Models=0 THEN A81
4320      IF Kthmod=0 THEN RETURN Ngdxyz
4330 A10:     IF Kthmod=Nthold THEN A20
4340      IF ABS(Kthmod)<=Maxmod THEN A12
4350      FOR I=1 TO Models
4360      IF Kthmod<>Model(I) THEN A11
4370      Nthmod=I
4380      GOTO A13
4390 A11:     NEXT I
4400      GOTO A83
4410 A12:     IF (Kthmod<1) OR (Kthmod>Models) THEN A83
4420      Nthmod=Kthmod
4430 A13:     Nthold=Kthmod
4440      Maxg=Max(Nthmod,1)
4450      Maxdg=Max(Nthmod,2)
4460      Maxd2g=Max(Nthmod,3)
4470      Ij10=Ijs(Nthmod,1)
4480      Ij20=Ijs(Nthmod,2)
4490      Ij30=Ijs(Nthmod,3)

```

```

4500 A20: CALL Vecxyz(Alat,Elon,Alt,Maxg,Ngdgc)
4510 ! C
4520 ! C TEST FOR NON-FATAL ERRORS
4530 ! C
4540 IF (Yr<Yrmin(Nthmod)) OR (Yr>Yrmax(Nthmod)) THEN Ngdxyz=1
4550 IF (Alt<Altmin(Nthmod)) OR (Alt>Altmax(Nthmod)) THEN Ngdxyz=Ngdxyz+
2
4560 X=0
4570 Y=0
4580 Z=0
4590 Ij=Ij10
4600 Ji0=0
4610 FOR I=1 TO Maxg
4620 Ji=Ji0
4630 Ji0=Ji0+Maxxyz
4640 FOR J=1 TO Maxg
4650 Ij=Ij+1
4660 Ji=Ji+1
4670 Gmnij=G(Ij)
4680 X=X+Xmn(Ji)*Gmnij
4690 Y=Y+Ymn(Ji)*Gmnij
4700 A21: Z=Z+Zmn(Ji)*Gmnij
4710 NEXT J
4720 A22: NEXT I
4730 Dx=0
4740 Dy=0
4750 Dz=0
4760 IF Maxdg<=0 THEN RETURN Ngdxyz
4770 Ij=Ij20
4780 Ji0=0
4790 FOR I=1 TO Maxdg
4800 Ji=Ji0
4810 Ji0=Ji0+Maxxyz
4820 FOR J=1 TO Maxdg
4830 Ij=Ij+1
4840 Ji=Ji+1
4850 Dgmnij=G(Ij)
4860 Dx=Dx+Xmn(Ji)*Dgmnij
4870 Dy=Dy+Ymn(Ji)*Dgmnij
4880 A23: Dz=Dz+Zmn(Ji)*Dgmnij
4890 NEXT J
4900 A24: NEXT I
4910 Del=Yr-Epoch(Nthmod)
4920 IF Maxd2g>0 THEN A30
4930 X=X+Del*Dx
4940 Y=Y+Del*Dy
4950 Z=Z+Del*Dz
4960 RETURN Ngdxyz
4970 A30: D2x=0
4980 D2y=0
4990 D2z=0
5000 Ij=Ij30
5010 Ji0=0
5020 FOR I=1 TO Maxd2g
5030 Ji=Ji0
5040 Ji0=Ji0+Maxxyz
5050 FOR J=1 TO Maxd2g

```

```

5060      Ij=Ij+1
5070      Ji=Ji+1
5080      Dgmni j=G(Ij)
5090      D2x=D2x+Xmn(Ji)*Dgmni j
5100      D2y=D2y+Ymn(Ji)*Dgmni j
5110 A31:  D2z=D2z+Zmn(Ji)*Dgmni j
5120      NEXT J
5130 A32:  NEXT I
5140      Del2=Del*Del
5150      X=X+Del*Dx+Del2*D2x
5160      Y=Y+Del*Dy+Del2*D2y
5170      Z=Z+Del*Dz+Del2*D2z
5180      Del2=2*Del
5190      Dx=Dx+Del2*D2x
5200      Dy=Dy+Del2*D2y
5210      Dz=Dz+Del2*D2z
5220      RETURN Ngdxyz
5230 !      ENTRY NGCXYZ
5240 ! C * ( YR, ALAT, ELON, ALT, NTHMOD ) C
      OUT
5250 ! C
5260 ! C      THIS ENTRY IS USED WHEN POSITION AND ALTITUDE ARE GEOCENTRIC. THE
5270 ! C      RETURNED MAGNETIC ELEMENTS ARE GEOCENTRIC.
5280 ! C
5290 Lngcxyz:Ngdgc=1
5300      GOTO A1
5310 ! C
5320 ! C      ERROR RETURNS
5330 ! C
5340 ! C      NOTE THAT A SECOND ERROR USES A DIVISION BY ZERO TO ABORT THE
      PROGRAM
5350 ! C
5360 ! C
5370 ! C      ERROR IN DATA CARDS OF MODEL
5380 A81:  Mistek=1
5390      PRINT "MISTEK=1 AT A81 --- PROBABLE ERROR IN DATA STATEMENTS OF THE
      MODEL"
5400      GOTO A89
5410 ! C
5420 ! C      ARRAY G INADEQUATELY DIMENSIONED
5430 ! C
5440 A82:  Mistek=2
5450      PRINT "MISTEK=2 AT A82 --- ARRAY G INADEQUATELY DIMENSIONED"
5460      GOTO A89
5470 ! C
5480 ! C      MODEL SPECIFIED BY KTHMOD NOT FOUND
5490 ! C
5500 A83:  Mistek=3
5510      PRINT "MISTEK=3 AT A83 --- MODEL SPECIFIED BY KTHMOD NOT FOUND"
5520      GOTO A89
5530 A89:  Ngdxyz=-Mistek/Killer
5540      Killer=0
5550      RETURN Ngdxyz
5560      FEND
5570 !
5580 !
5590 !

```

```

5600 SUB Vecxyz(Alat,Elon,Alt,Maxnew,Nycen)
5610 OPTION BASE 1
5620 RAD
5630 COM X,Y,Z,Dx,Dy,Dz,Models,Model$(20),Xmn(900),Ymn(900),Zmn(900)
5640 DIM P(900),D(900),Rxy(30),Rz(30),Sm(30),Cm(30)
5650 READ Rod,Oldth,Oldam,Oldlat,Oldalt,Oldr
5660 DATA 0.017453293, 9999., 9999., 9999., 9999., -99.
5670 READ Maxi,New,Radius,Max,Ntceno
5680 DATA 30, 1, 6371.2, -1, -1
5690 IF Max=Maxnew THEN GOTO B2
5700 Nyceno=-1
5710 Max=Maxnew
5720 IF New=0 THEN GOTO B2
5730 New=0
5740 Maxi1=Maxi+1
5750 Maxi2=Maxi+2
5760 ! C SET UP CONSTANTS IN LOWER TRIANGULAR OF P
5770 FOR J=1 TO Maxi
5780 Ji=J-Maxi
5790 A=(J-2)*(J-2)
5800 B=(2*J-3)*(2*J-5)
5810 FOR I=1 TO J
5820 Ji=Ji+Maxi
5830 B1: P(Ji)=(A-(I-1)^2)/B
5840 NEXT I
5850 NEXT J
5860 B2: Am=Elon*Rod
5870 !
5880 IF Nycen=Nyceno THEN GOTO B3
5890 Nyceno=Nycen
5900 Oldlat=9999
5910 Oldth=999
5920 Oldr=-1
5930 B3: IF Nycen<>0 THEN B9
5940 ! C
5950 ! C POSITIONS ARE GEODETIC
5960 ! C XMN, YMN, ZMN WILL BE GEODETIC
5970 ! C
5980 Vlat=Alat
5990 Valt=Alt
6000 IF (Vlat=Oldlat) AND (Valt=Oldalt) THEN B10
6010 Oldlat=Vlat
6020 Oldalt=Valt
6030 Gg=Vlat^2
6040 Rs=6378.160+Gg*(-.0064601509+Gg*(6.39897239E-7+Gg*(-2.3568098E-11+G
g*3.44645500E-16)))
6050 Del=Vlat*(1.16781720E-4+Gg*(-2.34129534E-8+Gg*(1.34088770E-12-Gg*2.
84450572E-17)))
6060 Hrs=Valt+Rs
6070 Beta=Rs*Del/Hrs
6080 Th=(90.0-Vlat)*Rod+Beta
6090 R=(Hrs-Beta*Valt*Del*.5)/Radius
6100 Bbeta=Beta^2
6110 Beta=Beta*(1+Bbeta*(-1/6.0+Bbeta/120.0))
6120 IF ABS(Beta)<1 THEN B8
6130 !

```

```

6140 !      SIMULATION OF FORTRAN "SIGN(A,B)" FUNCTION
6150      IF Beta>=0 THEN Beta=1
6160      IF Beta<0 THEN Beta=-1
6170 !
6180      Cbeta=0
6190      GOTO B10
6200 B8:    Cbeta=SQR(1-Beta^2)
6210      GOTO B10
6220 !
6230 ! C      POSITIONS ARE GEOCENTRIC
6240 ! C      XMN, YMN, ZMN WILL BE GEOCENTRIC
6250 ! C
6260 B9:    R=1+Alt/Radius
6270      Th=(90.0-Alat)*Rod
6280      Beta=0
6290 B10:   IF Th=0ldth THEN B20
6300 ! C      COMPUTE GAUSS PMN, DPMN
6310      Oldth=Th
6320      U=COS(Th)
6330      V=SIN(Th)
6340      IF V=0 THEN V=1.0E-20
6350      P(1)=1
6360      D(1)=0
6370      Ii=1
6380      FOR I=2 TO Max
6390      I1i1=Ii
6400      Ii=Ii+Maxi1
6410      I1i=Ii-1
6420      P(Ii)=V*P(I1i1)
6430      D(Ii)=U*P(I1i1)+V*D(I1i1)
6440      P(I1i)=U*P(I1i1)
6450      D(I1i)=U*D(I1i1)-V*P(I1i1)
6460 B12:   NEXT I
6470      Ii=1
6480      FOR I=3 TO Max
6490      I2j1=Ii
6500      Ji2=Ii+1
6510      Ii=Ii+Maxi1
6520      I2j=Ii-1
6530      FOR J=1 TO Max
6540      I2j2=I2j1
6550      I2j1=I2j
6560      I2j=I2j+Maxi
6570      Ji2=Ji2+1
6580      P(I2j)=U*P(I2j1)-P(Ji2)*P(I2j2)
6590      D(I2j)=U*D(I2j1)-P(Ji2)*D(I2j2)-V*P(I2j1)
6600 B13:   NEXT J
6610      NEXT I
6620 ! C
6630 ! C      STORE SINES AND COSINES OF LONGITUDE
6640 ! C
6650 B20:   IF Am=Oldam THEN B30
6660      Oldam=Am
6670      Cm(2)=COS(Am)
6680      Sm(2)=SIN(Am)
6690      Cm(1)=1

```

```

6700      Sm(1)=0
6710      FOR I=3 TO Max
6720      Sm(I)=Sm(I-1)*Cm(2)+Cm(I-1)*Sm(2)
6730      Cm(I)=Cm(I-1)*Cm(2)-Sm(I-1)*Sm(2)
6740 B22:  NEXT I
6750 ! C
6760 ! C      STORE POWERS OF R
6770 ! C
6780 B30:  IF R=Oldr THEN B40
6790      Oldr=R
6800      Rxy(1)=1/R/R
6810      Rz(1)=-Rxy(1)
6820      FOR I=2 TO Max
6830      Rxy(I)=Rxy(I-1)/R
6840      Rz(I)=-I*Rxy(I)
6850      NEXT I
6860 ! C
6870 ! C      COMPUTE XMN, YMN, ZMN ARRAYS
6880 ! C
6890 B40:  J1=1
6900      FOR J=2 TO Max
6910      J1=J1+Maxi
6920      Xmn(J1)=Rxy(J)*D(J1)
6930 B44:  Zmn(J1)=Rz(J)*P(J1)
6940      NEXT J
6950      V1=1/V
6960      Em=V1
6970      Ii=1
6980      FOR I=2 TO Max
6990      Cmi=Cm(I)
7000      Smi=Sm(I)
7010      Ij=Ii+1
7020      Ji=Ii
7030      Ii=Ii+Maxi1
7040      FOR J=I TO Max
7050      Ij=Ij+Maxi
7060      Ji=Ji+1
7070      Rxyj=Rxy(J)
7080      RdiJ=Rxyj*D(Ij)
7090      Xmn(Ij)=Cmi*RdiJ
7100      Xmn(Ji)=Smi*RdiJ
7110      Pij=P(Ij)
7120      Epr=Em*Pij*Rxyj
7130      Ymn(Ij)=Epr*Smi
7140      Ymn(Ji)=-Epr*Cmi
7150      Rp=Rz(J)*Pij
7160      Zmn(Ij)=Cmi*Rp
7170      Zmn(Ji)=Smi*Rp
7180 B45:  NEXT J
7190 B46:  Em=Em+V1
7200      NEXT I
7210 ! C
7220      IF Beta=0 THEN B50
7230      J1=0
7240      FOR I=1 TO Max
7250      Ij=J1
7260      J1=J1+Maxi

```

```

7270      FOR J=1 TO Max
7280      Ij=Ij+1
7290      IF Ij=1 THEN B48
7300      Xij=Xmn(Ij)
7310      Zij=Zmn(Ij)
7320      Xmn(Ij)=Cbeta*Xij+Beta*Zij
7330      Zmn(Ij)=Cbeta*Zij-Beta*Xij
7340 B48:  NEXT J
7350 B49:  NEXT I
7360 B50:  SUBEND
7370 !
7380 !
7390  SUB Smigau(G(*),Pointer,Maxg,Maxi)
7400      OPTION BASE 1
7410      RAD
7420      Root=Pointer-1
7430 !      G(*) AND POINTER ARE USED HERE TO SIMULATE THE PASSING OF ARRAYS
AS PARAMETERS IN FORTRAN
7440      DIM P(30,30)
7450 ! C
7460 ! C      THIS ROUTINE CONVERTS A (MAXG,MAXG) ARRAY OF SPHERICAL HARMONIC
7470 ! C      COEFFICIENTS, STORED IN AN ARRAY DIMENSIONED (MAXI,MAXI),
7480 ! C      FROM SCHMIDT-NORMALIZED TO GAUSS-NORMALIZED (MAIN ENTRY), OR
7490 ! C      FROM GAUSS-NORMALIZED TO SCHMIDT-NORMALIZED (GAUSMI ENTRY).
7500 ! C
7510 ! C
7520      READ New,Max
7530      DATA 0, 30
7540      Next=1
7550 D1:  IF New<>0 THEN D10
7560      New=1
7570      P(1,1)=0
7580      P(1,2)=1
7590      P(2,2)=1
7600      FOR I=3 TO Max
7610      H=I-1
7620      P(I,I)=P(I-1,I-1)*SQRT(1-.5/H)
7630      P(1,I)=P(1,I-1)*(2-1/H)
7640      H=H-1
7650      Hh=H^2
7660      FOR J=1 TO Max
7670      F=J-1
7680      P(I-1,J)=P(I-1,J-1)*(F+F-1)/SQRT(F*F-Hh)
7690 D3:  NEXT J
7700      NEXT I
7710      FOR I=2 TO Max
7720      FOR J=1 TO Max
7730      P(J,I-1)=P(I,J)
7740      NEXT J
7750      NEXT I
7760 D10:  IF Next=2 THEN D21
7770 D11:  FOR J=1 TO Maxg
7780      K=(J-1)*Maxi+Root
7790      FOR I=1 TO Maxg
7800      G(I+K)=G(I+K)*P(I,J)
7810 D12:  NEXT I
7820      NEXT J

```

```

7830      SUBEXIT
7840 D21:  FOR J=1 TO Maxg
7850      K=(J-1)*Maxi+Root
7860      FOR I=1 TO Maxg
7870      Pij=P(I,J)
7880      IF Pij=0 THEN D22
7890      G(I+K)=G(I+K)/Pij
7900 D22:  NEXT I
7910      NEXT J
7920      SUBEXIT
7930 !      ENTRY GAUSMI
7940 ! C    *      ( G, MAXG, MAXI )
      OUT
7950      Next=2
7960      GOTO D1
7970      SUBEND
7980 !
7990 !
8000      DEF FNAtan2(Y,X)
8010 !      EQUIVALENT OF THE ATAN2 FUNCTION IN FORTRAN
8020      RAD
8030      IF X=0 THEN Vert
8040      Ang=ATN(Y/X)
8050      IF X>0 THEN RETURN Ang
8060      IF Y<0 THEN Q3
8070      Ang=Ang+PI
8080      RETURN Ang
8090 Q3:   Ang=Ang-PI
8100      RETURN Ang
8110 Vert: IF Y<0 THEN Down
8120      Ang=PI/2
8130      RETURN Ang
8140 Down: Ang=-PI/2
8150      RETURN Ang
8160      FNEND

```

C

Program DXPRO, Sample Run

DXPRO is the program that takes DXGET files of raw data and produces velocity profiles on files and as plots. The algorithms are described in Section III.B.2.

DXPRO is usually run with 10 probe revolutions per average and with 5 revolutions between each average. The probe calibrations are usually pre-stored in the XCAL:T15 file but can be entered by hand. DXPRO can search the XCAL:T15 file by probe number or drop number. The earth's magnetic field components must be entered with the calibration.

DXPRO will use the HP 9845T internal graphics option or an HP 9872A or HP 9872S plotter.

The following pages show the operator input and program output. The program listing follows.

DXPROZ 81:04:07:18:18:47
INPUT FILE NO. 1 ? (CLEAR TO TERMINATE)

620RD

EDIT COMMENTS

11:10:04:27:40 INTENSIVE SURVEY HEADING 270

NUMBER OF SCANS IN EACH AVERAGING WINDOW ?

10

STEPPING INCREMENT?

5

EDIT calibration file name. (BLANK TO ENTER CAL BY HAND)

XCAL :T15

XTVP SERIAL NO. ? (ZERO TO SEARCH BY DROP NO.)

871

READING XCAL :T15

EDIT: Probe Mod Gcc Gcor Gef Evco Cucc Drop Fh Fz
500 1 871 6 3628 1838 25230 1001 1000 620 .204-.490

OUTPUT FILE NAME?

620P

INPUT FILE NO. 2 ? (CLEAR TO TERMINATE)

PLOTTER ? (0=NONE, 1=GRAPHICS, 2=9872A, 3=9872S)

3

LOOKING FOR PF ON

LAUNCH-TIME=

11:10:04:27:52

12.2378

ISCAN= 98

DOWN-TIME=

11:10:04:29:06

86.24273

ISCAN= 673

PROCESSING FILE 1 . IFILE=620RD, OFILE=620P

Z	Temp	U	V	W	Rotf	Area	Uw	Vc0a	Zcdp	Ve0a	Ve0p	Fefb	Fccb	Ver
-7	10.18	33.5	12.4	-454	5.23	882	94	59	-7.6	4.36	118.3	2453	4503	29.9
-11	10.18	28.4	.1	-454	6.27	798	94	64	-8.3	4.85	113.9	2438	4505	9.0
-15	10.18	44.0	-12.3	-454	6.60	771	94	65	-6.8	5.69	118.1	2477	4505	1.3
-18	10.18	39.8	-18.4	-454	6.75	767	94	66	-6.5	5.90	114.9	2465	4504	1.1
-21	10.18	32.9	-22.5	-454	6.83	767	94	67	-6.3	5.98	111.1	2485	4504	1.0
-24	10.18	26.2	-22.0	-454	6.90	763	94	67	-6.5	5.88	108.2	2498	4504	1.1

-28	10.18	20.4	-19.5	-454	6.97	761	94	68	-6.5	5.70	105.7	2498	4504	.9
-31	10.18	16.2	-15.7	-454	7.00	764	94	69	-6.2	5.48	103.6	2497	4505	.9
-34	10.18	15.4	-9.9	-453	7.01	761	94	68	-6.2	5.19	103.6	2501	4505	.7
-37	10.18	16.4	-5.4	-453	6.99	759	94	68	-6.1	4.97	104.5	2501	4504	.6
-41	10.18	18.9	-1.7	-453	6.99	753	94	67	-6.3	4.82	106.4	2503	4505	.5
-44	10.17	21.3	-.6	-453	6.99	752	94	67	-6.2	4.78	107.9	2504	4504	.5
-47	10.18	24.0	-2.8	-453	6.96	750	94	67	-6.0	4.92	108.9	2505	4504	.7
-50	10.17	26.0	-4.7	-453	6.93	749	94	67	-6.1	5.04	109.9	2506	4504	.5
-54	10.17	26.3	-6.5	-453	6.92	746	94	66	-6.1	5.12	109.8	2506	4504	.5
-57	10.17	25.2	-8.9	-453	6.92	745	94	66	-6.1	5.23	108.9	2506	4504	.3
-60	10.06	24.6	-10.4	-453	6.90	741	94	66	-5.9	5.29	108.2	2506	4504	.6
-64	9.27	19.1	-16.5	-453	6.88	751	94	66	-6.2	5.53	105.0	2507	4504	1.6
-67	8.17	6.0	-26.6	-453	6.93	792	94	70	-6.5	5.95	98.3	2506	4504	1.7
-70	7.55	-4.2	-31.0	-452	6.98	822	94	74	-6.3	6.17	93.3	2506	4504	1.0
Z	Temp	U	V	W	Rotf	Area	Uw	Vc0a	Zcdp	Ve0a	Ve0p	Fefb	Fccb	Ver
-73	7.18	-10.2	-36.7	-452	6.98	846	94	76	-6.1	6.46	90.6	2506	4504	.8
-77	6.79	-14.0	-39.5	-452	6.94	859	94	76	-6.0	6.62	88.9	2506	4504	.5
-80	6.59	-16.0	-38.5	-452	6.90	855	94	76	-6.0	6.58	88.1	2506	4504	.3
-83	6.48	-16.1	-35.1	-452	6.89	840	94	74	-6.0	6.41	87.8	2505	4504	.5
-86	6.43	-16.2	-28.6	-452	6.86	815	94	72	-5.7	6.09	87.1	2505	4504	.4
-90	6.39	-14.6	-23.6	-452	6.84	793	94	69	-6.0	5.84	87.8	2505	4503	.6
-93	6.33	-13.0	-16.1	-452	6.82	764	94	67	-6.0	5.46	88.1	2505	4503	.6
-96	6.26	-11.8	-10.1	-452	6.81	737	94	64	-5.9	5.16	88.4	2505	4503	.4
-100	6.16	-10.2	-6.6	-452	6.82	722	94	63	-5.9	4.97	89.1	2505	4503	.5
-103	6.12	-8.7	-8.4	-451	6.80	723	93	63	-5.9	5.05	90.0	2505	4503	.6
-106	6.09	-8.9	-12.4	-451	6.77	733	93	64	-6.0	5.25	90.1	2505	4503	.4
-110	6.02	-9.0	-10.0	-451	6.78	729	93	63	-6.1	5.13	90.1	2505	4502	.8
-113	5.92	-4.2	-7.3	-451	6.81	718	93	63	-6.0	4.98	92.6	2505	4502	.9
-116	5.86	-.6	-3.6	-451	6.81	704	93	62	-5.8	4.79	94.4	2505	4503	1.0
-120	5.87	2.6	8.3	-451	6.80	669	93	58	-6.0	4.21	96.7	2505	4503	1.0
-123	5.83	5.2	15.2	-451	6.81	648	93	57	-6.2	3.87	98.9	2505	4502	.8
-126	5.81	7.5	18.6	-451	6.82	648	93	57	-6.1	3.71	100.8	2505	4502	.7
-130	5.77	5.6	19.2	-451	6.82	656	93	57	-6.2	3.67	99.5	2505	4502	.5
-133	5.73	4.1	17.4	-451	6.80	679	93	59	-6.1	3.76	98.1	2505	4502	.3
-136	5.72	6.1	14.6	-450	6.78	700	93	61	-6.1	3.90	99.4	2505	4502	.6
Z	Temp	U	V	W	Rotf	Area	Uw	Vc0a	Zcdp	Ve0a	Ve0p	Fefb	Fccb	Ver
-139	5.72	6.3	7.8	-450	6.78	726	93	63	-6.1	4.24	99.3	2505	4502	.5
-143	5.72	8.7	4.5	-450	6.78	742	93	64	-6.0	4.41	100.5	2505	4502	.6
-146	5.70	10.2	.6	-450	6.76	750	93	65	-5.9	4.61	101.1	2505	4502	.7
-149	5.67	9.5	-5.4	-450	6.75	766	93	66	-6.0	4.89	100.4	2505	4502	.6
-153	5.63	9.3	-10.2	-450	6.76	779	93	67	-6.1	5.13	100.1	2505	4502	.4
-156	5.60	9.3	-10.6	-450	6.77	775	93	67	-6.0	5.15	100.0	2505	4502	.4
-159	5.59	8.9	-7.1	-450	6.76	760	93	66	-5.8	4.98	99.9	2505	4502	.4
-163	5.59	9.4	-5.4	-450	6.74	751	93	65	-5.8	4.89	100.2	2505	4502	.3
-166	5.60	7.3	-3.8	-450	6.74	744	93	64	-5.9	4.80	99.2	2505	4502	.5
-169	5.61	5.5	-3.2	-449	6.76	742	93	64	-6.1	4.77	98.3	2505	4502	.3
-173	5.61	4.2	-3.0	-449	6.77	744	93	65	-5.9	4.75	97.4	2505	4502	.5
-176	5.58	2.3	-4.1	-449	6.75	751	93	65	-5.9	4.80	96.2	2505	4502	.4
-179	5.55	1.9	-4.5	-449	6.74	754	93	65	-6.0	4.82	96.0	2505	4502	.4
-183	5.52	1.6	-4.9	-449	6.75	757	93	65	-6.0	4.84	95.9	2505	4502	.3
-186	5.49	2.1	-5.0	-449	6.75	757	93	66	-5.9	4.85	96.1	2505	4502	.3
-189	5.45	2.3	-3.9	-449	6.74	753	93	65	-5.9	4.79	96.2	2505	4502	.3
-193	5.41	2.5	-3.5	-449	6.72	750	93	65	-6.0	4.77	96.4	2505	4501	.4
-196	5.37	2.8	-3.8	-449	6.73	751	93	65	-6.0	4.78	96.5	2504	4501	.4
-199	5.32	3.9	-1.6	-449	6.74	744	93	64	-5.8	4.67	97.1	2505	4502	.3
-203	5.28	3.9	.1	-448	6.73	736	93	63	-5.8	4.59	97.1	2505	4502	.3
Z	Temp	U	V	W	Rotf	Area	Uw	Vc0a	Zcdp	Ve0a	Ve0p	Fefb	Fccb	Ver

-206	5.24	4.3	.4	-448	6.71	737	93	63	-5.9	4.58	97.4	2505	4502	.3
-209	5.22	4.5	-1.1	-448	6.71	740	93	64	-6.0	4.65	97.7	2505	4502	.3
-213	5.17	5.9	-3.1	-448	6.74	744	93	64	-5.9	4.75	98.4	2504	4502	.3
-216	5.11	6.9	-1.9	-448	6.73	743	93	64	-5.7	4.69	98.8	2505	4502	.3
-219	5.05	7.6	-2.9	-448	6.70	745	93	64	-5.7	4.74	99.2	2504	4502	.4
-223	5.02	7.9	-4.9	-448	6.69	747	93	64	-5.9	4.84	99.4	2505	4502	.3
-226	5.01	8.3	-4.1	-448	6.71	745	93	64	-6.0	4.80	99.8	2505	4502	.4
-229	4.99	9.2	-2.5	-448	6.72	738	93	64	-5.9	4.73	100.3	2505	4502	.3
-233	4.97	9.0	-2.4	-448	6.70	736	93	63	-5.8	4.72	100.1	2505	4502	.3
-236	4.93	10.1	-3.3	-447	6.68	739	93	63	-6.0	4.77	100.9	2505	4502	.4
-239	4.89	11.8	-4.6	-447	6.70	739	93	63	-6.0	4.84	101.8	2505	4502	.4
-243	4.86	13.3	-3.4	-447	6.71	735	93	63	-5.8	4.79	102.6	2504	4502	.5
-246	4.84	13.8	-1.6	-447	6.69	728	93	62	-5.7	4.71	103.0	2505	4502	.4
-249	4.82	14.0	-1.7	-447	6.67	727	93	62	-5.9	4.71	103.2	2505	4502	.4
-253	4.81	14.4	-3.9	-447	6.68	735	93	63	-5.9	4.82	103.3	2505	4502	.3
-256	4.79	13.9	-4.4	-447	6.69	739	93	63	-5.9	4.84	103.0	2505	4502	.3
-260	4.76	14.1	-3.9	-447	6.69	739	93	63	-5.8	4.81	103.0	2505	4502	.3
-263	4.73	14.3	-3.7	-447	6.65	738	92	63	-5.6	4.81	103.0	2505	4502	.4
-266	4.70	14.2	-2.3	-447	6.64	736	92	63	-5.9	4.73	103.3	2504	4502	.4
-270	4.68	14.5	-2.4	-446	6.67	737	92	63	-6.1	4.74	103.7	2504	4502	.3
Z	Temp	U	V	W	Rotf	Area	Uw	Vc0a	Zcdp	Ve0a	Ve0p	Fefb	Fccb	Ver
-273	4.65	14.7	-3.2	-446	6.69	739	92	63	-6.0	4.78	103.7	2505	4502	.3
-276	4.61	13.8	-3.6	-446	6.67	743	92	64	-5.8	4.79	102.9	2504	4502	.4
-280	4.63	13.9	-4.0	-446	6.65	745	92	64	-5.7	4.81	102.8	2504	4502	.4
-283	4.63	13.4	-5.4	-446	6.66	746	92	64	-5.9	4.88	102.6	2505	4502	.3
-286	4.61	12.3	-6.5	-446	6.68	749	92	64	-5.8	4.92	101.9	2505	4502	.3
-290	4.57	11.7	-6.7	-446	6.66	752	92	64	-5.7	4.93	101.3	2504	4502	.3
-293	4.57	11.9	-6.1	-446	6.63	752	92	64	-5.7	4.90	101.5	2504	4502	.3
-296	4.56	11.2	-4.6	-446	6.63	746	92	63	-6.0	4.82	101.5	2504	4502	.4
-300	4.56	11.6	-4.0	-446	6.66	743	92	63	-6.1	4.79	101.8	2504	4502	.4
-303	4.55	12.5	-2.4	-445	6.66	740	92	63	-5.9	4.72	102.3	2504	4502	.3
-306	4.53	12.7	-1.1	-445	6.64	736	92	63	-5.8	4.66	102.5	2504	4502	.2
-310	4.49	11.4	-1.1	-445	6.63	737	92	63	-5.8	4.65	101.6	2504	4502	.3
-313	4.43	11.2	-1.0	-445	6.64	738	92	63	-5.9	4.64	101.6	2504	4502	.3
-316	4.42	12.7	.0	-445	6.66	736	92	63	-6.0	4.60	102.7	2504	4501	.4
-320	4.39	14.6	-.7	-445	6.64	738	92	63	-5.7	4.64	103.6	2504	4501	.3
-323	4.36	15.1	-2.1	-445	6.61	740	92	63	-5.7	4.72	103.7	2504	4501	.4
-327	4.33	14.3	-4.4	-445	6.62	746	92	63	-6.1	4.82	103.4	2504	4501	.5
-330	4.32	13.3	-5.4	-445	6.64	750	92	64	-5.9	4.86	102.5	2504	4501	.5
-333	4.31	12.5	-3.0	-444	6.64	744	92	63	-5.7	4.74	102.1	2504	4502	.4
-337	4.29	11.8	.1	-444	6.61	734	92	62	-5.6	4.58	101.9	2504	4501	.4
Z	Temp	U	V	W	Rotf	Area	Uw	Vc0a	Zcdp	Ve0a	Ve0p	Fefb	Fccb	Ver
-340	4.28	11.9	-.0	-444	6.59	734	92	62	-5.9	4.59	102.1	2504	4501	.3
-343	4.29	11.6	-.9	-444	6.61	740	92	63	-5.8	4.62	101.9	2504	4501	.2
-347	4.28	11.0	-.5	-444	6.62	742	92	63	-5.9	4.60	101.6	2504	4502	.3
-350	4.26	11.7	1.0	-444	6.60	738	92	62	-5.7	4.53	101.9	2504	4502	.3
-353	4.23	11.8	.1	-444	6.59	739	92	62	-5.7	4.58	101.9	2504	4501	.3
-357	4.22	10.4	-.5	-444	6.60	744	92	63	-5.9	4.60	101.3	2504	4501	.4
-360	4.21	9.1	-1.5	-444	6.61	748	92	63	-5.9	4.64	100.3	2504	4501	.4
-363	4.21	7.4	-1.7	-444	6.61	751	92	64	-5.8	4.64	99.3	2504	4502	.3
-367	4.20	6.2	-2.6	-443	6.59	754	92	64	-5.7	4.68	98.3	2504	4502	.3
-370	4.20	6.3	-3.9	-443	6.58	758	92	64	-5.7	4.74	98.3	2504	4502	.3
-374	4.18	6.2	-2.7	-443	6.59	758	92	64	-5.7	4.68	98.4	2504	4502	.4
-377	4.17	6.4	-.2	-443	6.60	751	92	64	-5.7	4.55	98.6	2504	4501	.4
-380	4.17	6.7	1.0	-443	6.58	747	92	63	-5.6	4.50	98.7	2504	4501	.3
-384	4.16	6.2	1.6	-443	6.57	743	92	63	-5.8	4.47	98.6	2504	4501	.3
-387	4.15	6.7	2.4	-443	6.58	741	92	62	-5.8	4.42	98.9	2504	4502	.3

-390	4.15	7.2	2.5	-443	6.60	741	92	63	-5.7	4.42	99.2	2504	4502	.3
-394	4.14	7.7	2.7	-443	6.59	739	92	62	-5.7	4.41	99.5	2504	4501	.3
-397	4.14	7.3	1.9	-443	6.57	740	92	62	-5.6	4.45	99.2	2504	4501	.5
-401	4.13	5.8	.1	-442	6.56	746	92	63	-5.8	4.53	98.3	2504	4502	.5
-404	4.12	6.4	-1.3	-442	6.58	753	92	63	-5.8	4.61	98.6	2504	4502	.4
Z	Temp	U	V	W	Rotf	Area	Uw	Vc0a	Zcdp	Ve0a	Ve0p	Fefb	Fccb	Ver
-407	4.10	5.9	-1.2	-442	6.58	752	92	63	-5.7	4.60	98.2	2504	4502	.3
-411	4.09	6.9	-1.0	-442	6.57	748	92	63	-5.7	4.59	98.8	2504	4502	.3
-414	4.08	7.2	-2.0	-442	6.56	750	92	63	-5.8	4.64	99.1	2504	4501	.4
-417	4.08	6.3	-2.7	-442	6.58	751	92	63	-5.9	4.67	98.6	2504	4501	.3
-421	4.07	6.9	-3.1	-442	6.59	751	92	63	-5.8	4.69	98.8	2504	4502	.4
-424	4.07	6.8	-2.6	-442	6.58	749	91	63	-5.6	4.66	98.6	2504	4502	.4
-427	4.07	6.3	-3.0	-442	6.55	747	91	63	-5.6	4.68	98.3	2504	4502	.4
-431	4.07	5.6	-3.5	-442	6.55	748	91	63	-5.8	4.70	98.0	2504	4501	.3
-434	4.06	6.1	-4.9	-441	6.57	750	91	63	-5.8	4.77	98.4	2504	4501	.4
-438	4.05	5.6	-6.5	-441	6.56	753	91	63	-5.6	4.85	97.8	2504	4502	.4
-441	4.03	5.2	-6.1	-441	6.54	750	91	63	-5.6	4.82	97.5	2504	4501	.4
-444	4.02	5.3	-4.7	-441	6.54	745	91	62	-5.8	4.75	97.9	2504	4501	.4
-448	4.02	4.7	-3.5	-441	6.56	742	91	62	-6.0	4.69	97.7	2504	4502	.3
-451	4.01	4.0	-3.7	-441	6.58	742	91	62	-5.9	4.70	97.2	2504	4502	.3
-454	4.01	4.6	-4.6	-441	6.56	744	91	63	-5.7	4.75	97.3	2504	4502	.3
-458	4.01	5.2	-3.5	-441	6.55	742	91	62	-5.7	4.69	97.7	2504	4502	.3
-461	4.01	5.4	-5.3	-441	6.55	745	91	62	-5.7	4.78	97.8	2504	4502	.3
-464	4.01	4.5	-6.1	-440	6.55	749	91	63	-5.9	4.81	97.4	2504	4502	.4
-468	4.00	4.7	-8.1	-440	6.55	752	91	63	-5.7	4.91	97.3	2504	4502	.4
-471	4.00	4.3	-7.6	-440	6.53	751	91	63	-5.6	4.89	96.9	2504	4502	.4
Z	Temp	U	V	W	Rotf	Area	Uw	Vc0a	Zcdp	Ve0a	Ve0p	Fefb	Fccb	Ver
-475	3.99	4.0	-6.3	-440	6.51	748	91	62	-5.8	4.82	97.0	2504	4502	.4
-478	3.99	4.4	-4.9	-440	6.54	743	91	62	-5.8	4.75	97.4	2504	4502	.3
-481	3.98	6.1	-3.9	-440	6.55	739	91	62	-5.7	4.70	98.3	2504	4502	.4
-485	3.98	6.2	-3.1	-440	6.54	736	91	62	-5.7	4.67	98.4	2504	4502	.3
-488	3.97	5.4	-4.7	-440	6.52	739	91	62	-5.6	4.74	97.7	2504	4502	.3
-491	3.97	5.2	-6.9	-440	6.52	745	91	62	-5.8	4.85	97.7	2504	4502	.3
-495	3.97	4.7	-8.4	-440	6.54	750	91	63	-5.9	4.92	97.5	2504	4502	.2
-498	3.96	4.8	-10.2	-439	6.54	753	91	63	-5.7	5.01	97.3	2504	4502	.3
-501	3.96	4.3	-9.6	-439	6.51	753	91	63	-5.5	4.98	96.8	2504	4502	.3
-505	3.95	4.5	-10.6	-439	6.50	753	91	63	-5.6	5.02	97.0	2504	4502	.4
-508	3.94	4.8	-14.0	-439	6.52	759	91	63	-5.8	5.19	97.3	2504	4501	.4
-512	3.94	4.7	-12.1	-439	6.53	754	91	63	-5.7	5.10	97.2	2504	4501	.4
-515	3.93	5.3	-10.5	-439	6.52	746	91	62	-5.6	5.02	97.4	2504	4502	.3
-518	3.92	6.6	-9.4	-439	6.50	741	91	62	-5.5	4.97	98.2	2504	4502	.3
-522	3.91	7.9	-9.8	-439	6.50	738	91	61	-5.7	4.99	99.0	2504	4502	.3
-525	3.91	8.2	-10.5	-439	6.51	739	91	62	-5.7	5.03	99.2	2504	4502	.2
-528	3.89	8.8	-10.1	-439	6.52	736	91	61	-5.7	5.01	99.5	2504	4502	.2
-532	3.88	8.0	-9.0	-438	6.49	735	91	61	-5.5	4.95	99.0	2504	4502	.2
-535	3.88	8.1	-8.0	-438	6.49	733	91	61	-5.6	4.90	99.2	2504	4502	.2
-539	3.87	7.9	-9.2	-438	6.51	736	91	61	-5.8	4.96	99.2	2505	4502	.3
Z	Temp	U	V	W	Rotf	Area	Uw	Vc0a	Zcdp	Ve0a	Ve0p	Fefb	Fccb	Ver
-542	3.86	7.6	-8.1	-438	6.53	735	91	62	-5.8	4.90	99.0	2504	4502	.3
-545	3.86	8.9	-8.7	-438	6.51	738	91	62	-5.6	4.93	99.5	2504	4502	.3
-549	3.85	9.4	-8.6	-438	6.48	741	91	62	-5.6	4.93	99.8	2504	4502	.3
-552	3.85	9.2	-8.9	-438	6.49	741	91	62	-5.7	4.94	99.9	2504	4502	.4
-555	3.84	8.3	-9.7	-438	6.51	742	91	62	-5.8	4.98	99.4	2504	4502	.3
-559	3.83	7.7	-10.4	-438	6.50	744	91	62	-5.6	5.01	98.9	2504	4502	.3
-562	3.82	7.3	-10.1	-437	6.47	745	91	62	-5.6	4.99	98.6	2504	4502	.3
-565	3.81	6.9	-8.7	-437	6.48	743	91	62	-5.8	4.92	98.6	2504	4502	.4
-569	3.81	7.1	-8.7	-437	6.50	743	91	62	-5.8	4.92	98.7	2504	4501	.4

-572	3.79	5.9	-9.2	-437	6.49	746	91	62	-5.6	4.94	97.8	2504	4502	.3
-576	3.78	5.5	-9.4	-437	6.47	750	91	62	-5.6	4.95	97.5	2504	4501	.3
-579	3.77	4.0	-9.6	-437	6.47	751	90	62	-5.7	4.95	96.8	2504	4502	.3
-582	3.76	3.4	-9.9	-437	6.48	751	90	62	-5.7	4.96	96.5	2504	4502	.3
-586	3.76	2.8	-9.3	-437	6.49	752	90	63	-5.6	4.93	96.1	2504	4502	.3
-589	3.75	3.9	-9.8	-437	6.47	750	90	62	-5.6	4.96	96.6	2504	4501	.4
-592	3.74	4.3	-9.6	-437	6.46	747	90	62	-5.8	4.95	97.1	2504	4501	.4
-596	3.74	3.7	-8.9	-436	6.48	745	90	62	-5.8	4.91	96.8	2504	4501	.3
-599	3.72	4.8	-8.6	-436	6.48	743	90	62	-5.5	4.90	97.1	2504	4501	.4
-603	3.71	5.1	-8.9	-436	6.46	743	90	62	-5.5	4.91	97.3	2504	4501	.4
-606	3.71	4.9	-8.5	-436	6.46	741	90	61	-5.6	4.89	97.3	2504	4501	.4
Z	Temp	U	V	W	Rotf	Area	Uw	Vc0a	Zcdp	Ve0a	Ve0p	Fefb	Fccb	Ver
-609	3.70	4.5	-7.4	-436	6.47	739	90	61	-5.7	4.83	97.2	2504	4501	.4
-613	3.69	5.3	-8.1	-436	6.47	741	90	61	-5.6	4.87	97.6	2504	4501	.3
-616	3.68	4.9	-9.2	-436	6.46	745	90	62	-5.4	4.92	97.1	2504	4501	.4
-619	3.67	4.1	-9.8	-436	6.44	747	90	62	-5.6	4.95	96.7	2504	4501	.5
-623	3.66	3.2	-8.7	-436	6.46	747	90	62	-5.7	4.89	96.5	2504	4501	.4
-626	3.66	2.6	-8.0	-435	6.46	745	90	62	-5.5	4.86	95.9	2504	4501	.4
-630	3.65	2.2	-8.2	-435	6.45	746	90	62	-5.5	4.87	95.7	2504	4501	.2
-633	3.64	1.8	-8.3	-435	6.44	746	90	62	-5.6	4.86	95.5	2504	4501	.2
-636	3.64	2.3	-8.1	-435	6.46	746	90	62	-5.8	4.86	96.0	2504	4501	.3
-640	3.63	1.8	-7.6	-435	6.47	744	90	62	-5.6	4.83	95.5	2504	4501	.3
-643	3.62	1.4	-6.7	-435	6.45	744	90	62	-5.5	4.78	95.2	2504	4501	.3
-646	3.61	.9	-7.6	-435	6.44	747	90	62	-5.6	4.83	95.0	2504	4501	.3
-650	3.61	.4	-6.6	-435	6.45	745	90	62	-5.7	4.77	94.8	2504	4501	.3
-653	3.60	.7	-5.5	-435	6.46	742	90	61	-5.7	4.72	94.9	2504	4501	.3
-657	3.59	1.3	-5.6	-435	6.44	741	90	61	-5.5	4.73	95.2	2504	4502	.3
-660	3.59	1.1	-6.4	-434	6.44	742	90	61	-5.6	4.77	95.1	2504	4502	.3
-663	3.59	1.4	-5.5	-434	6.45	745	90	62	-5.6	4.72	95.3	2504	4501	.3
-667	3.58	1.4	-4.8	-434	6.45	745	90	62	-5.6	4.68	95.3	2504	4501	.2
-670	3.58	1.0	-3.8	-434	6.43	739	90	61	-5.6	4.63	95.1	2504	4501	.2
-673	3.57	1.6	-5.3	-434	6.44	741	90	61	-5.7	4.71	95.5	2504	4501	.3
Z	Temp	U	V	W	Rotf	Area	Uw	Vc0a	Zcdp	Ve0a	Ve0p	Fefb	Fccb	Ver
-677	3.56	2.6	-5.6	-434	6.46	744	90	62	-5.7	4.72	96.1	2504	4501	.3
-680	3.56	3.3	-5.5	-434	6.45	742	90	61	-5.4	4.72	96.2	2504	4501	.3
-684	3.56	3.1	-5.2	-434	6.42	742	90	61	-5.5	4.70	96.2	2504	4501	.4
-687	3.56	3.4	-6.6	-434	6.43	743	90	61	-5.7	4.77	96.6	2504	4501	.3
-690	3.55	3.0	-6.2	-434	6.44	744	90	61	-5.6	4.75	96.2	2504	4501	.3
-694	3.54	2.9	-4.9	-433	6.42	741	90	61	-5.3	4.68	95.9	2504	4501	.2
-697	3.54	2.0	-4.2	-433	6.40	741	90	61	-5.6	4.65	95.7	2504	4501	.2
-700	3.53	1.8	-3.3	-433	6.42	741	90	61	-5.8	4.60	95.7	2504	4501	.2
-704	3.52	2.3	-3.1	-433	6.43	740	90	61	-5.5	4.59	95.8	2504	4501	.2
-707	3.51	2.1	-3.7	-433	6.40	742	90	61	-5.4	4.61	95.5	2504	4501	.4
-711	3.51	.1	-4.3	-433	6.42	746	90	61	-5.6	4.64	94.5	2504	4502	.4
-714	3.50	.0	-4.1	-433	6.43	750	90	62	-5.5	4.63	94.4	2504	4502	.3
-717	3.49	-.8	-4.8	-433	6.41	751	90	62	-5.4	4.67	93.8	2504	4502	.4
-721	3.49	-.4	-5.5	-433	6.41	749	90	62	-5.6	4.70	94.2	2504	4502	.3
-724	3.49	-.4	-5.4	-432	6.42	745	90	61	-5.6	4.69	94.2	2504	4502	.4
-727	3.48	-.3	-3.4	-432	6.41	741	90	61	-5.4	4.59	94.1	2504	4502	.4
-731	3.47	.7	-2.9	-432	6.40	739	90	61	-5.6	4.57	94.9	2504	4501	.2
-734	3.46	1.4	-3.1	-432	6.41	740	89	61	-5.7	4.58	95.4	2504	4501	.3
-737	3.46	2.0	-3.1	-432	6.42	739	89	61	-5.6	4.58	95.7	2504	4501	.3
-741	3.45	2.3	-3.0	-432	6.41	740	89	61	-5.5	4.57	95.7	2504	4502	.3
Z	Temp	U	V	W	Rotf	Area	Uw	Vc0a	Zcdp	Ve0a	Ve0p	Fefb	Fccb	Ver
-744	3.45	3.0	-3.0	-432	6.40	740	89	61	-5.6	4.57	96.3	2504	4501	.2
-748	3.45	3.5	-2.2	-432	6.41	738	89	61	-5.6	4.53	96.6	2504	4501	.3
-751	3.44	2.7	-2.4	-432	6.40	738	89	61	-5.5	4.54	96.0	2504	4501	.3
-754	3.43	2.0	-2.5	-432	6.39	740	89	61	-5.6	4.54	95.6	2504	4501	.3

-758	3.43	1.8	-1.8	-431	6.39	741	89	61	-5.6	4.51	95.6	2504	4502	.5
-761	3.42	.9	-2.1	-431	6.39	742	89	61	-5.5	4.52	94.9	2504	4501	.5
-764	3.42	.9	-3.5	-431	6.37	745	89	61	-5.5	4.59	94.9	2504	4501	.4
-768	3.41	.8	-3.2	-431	6.37	745	89	61	-5.5	4.57	94.8	2504	4502	.4
-771	3.41	.3	-1.8	-431	6.39	741	89	61	-5.5	4.50	94.5	2504	4502	.3
-775	3.41	.4	-.8	-431	6.38	736	89	60	-5.6	4.45	94.7	2504	4502	.3
-778	3.40	.9	-.7	-431	6.38	735	89	60	-5.6	4.44	95.0	2504	4502	.3
-781	3.39	1.2	-1.3	-431	6.37	739	89	60	-5.5	4.47	95.1	2504	4502	.3
-785	3.38	1.7	-1.7	-431	6.36	742	89	60	-5.4	4.49	95.3	2504	4502	.3
-788	3.37	1.8	-1.4	-430	6.35	740	89	60	-5.5	4.48	95.5	2504	4502	.3
-792	3.37	1.6	-1.9	-430	6.36	740	89	60	-5.6	4.50	95.4	2505	4502	.3
-795	3.36	1.4	-1.2	-430	6.35	742	89	60	-5.3	4.46	95.0	2504	4502	.3
-798	3.35	1.2	-.5	-430	6.36	740	89	60	-5.5	4.43	95.1	2505	4502	.5
-802	3.34	-.1	-.3	-430	6.36	739	89	60	-5.5	4.42	94.2	2504	4502	.5
-805	3.34	-1.2	-.3	-430	6.35	741	89	60	-5.4	4.42	93.5	2504	4502	.4
-808	3.33	-1.7	-.4	-430	6.34	743	89	60	-5.6	4.42	93.3	2504	4502	.3
Z	Temp	U	V	W	Rotf	Area	Uw	Vc0a	Zcdp	Ve0a	Ve0p	Fefb	Fccb	Ver
-812	3.33	-2.0	-.3	-430	6.35	744	89	61	-5.6	4.41	93.1	2504	4502	.3
-815	3.33	-1.9	-1.3	-430	6.33	746	89	61	-5.3	4.46	93.0	2504	4502	.3
-819	3.32	-3.0	-.9	-429	6.33	746	89	60	-5.5	4.44	92.4	2504	4502	.3
-822	3.32	-3.0	.4	-429	6.33	743	89	60	-5.7	4.38	92.5	2504	4502	.3
-825	3.31	-2.7	.1	-429	6.32	743	89	60	-5.5	4.39	92.6	2504	4502	.3
-829	3.31	-4.1	.0	-429	6.32	743	89	60	-5.6	4.40	91.7	2504	4502	.4
-832	3.30	-3.9	1.1	-429	6.32	744	89	60	-5.4	4.34	91.7	2504	4502	.4
-836	3.29	-3.7	.1	-429	6.31	746	89	60	-5.4	4.39	91.8	2505	4502	.4
-839	3.28	-3.9	-.4	-429	6.32	749	89	61	-5.5	4.42	91.8	2504	4502	.3
-842	3.28	-5.4	-.8	-429	6.31	749	89	61	-5.4	4.44	90.8	2504	4502	.3
-846	3.27	-6.1	-1.5	-429	6.30	751	89	61	-5.4	4.47	90.4	2504	4502	.3
-849	3.27	-6.9	-1.7	-429	6.30	751	89	61	-5.5	4.49	90.0	2504	4502	.3
-853	3.27	-7.4	-2.0	-428	6.30	753	89	61	-5.4	4.50	89.6	2504	4502	.4
-856	3.26	-7.5	-2.7	-428	6.29	753	89	61	-5.5	4.53	89.6	2505	4502	.4
-859	1.78	77.2	-3.9	-428	6.23	1612	89	129	72.9	5.96	55.7	2450	4507	

282.997415541 2D.D

-862 -1.98 347.2-259.3 -428 7.1610727 89 985

-219.813728993 3D.D

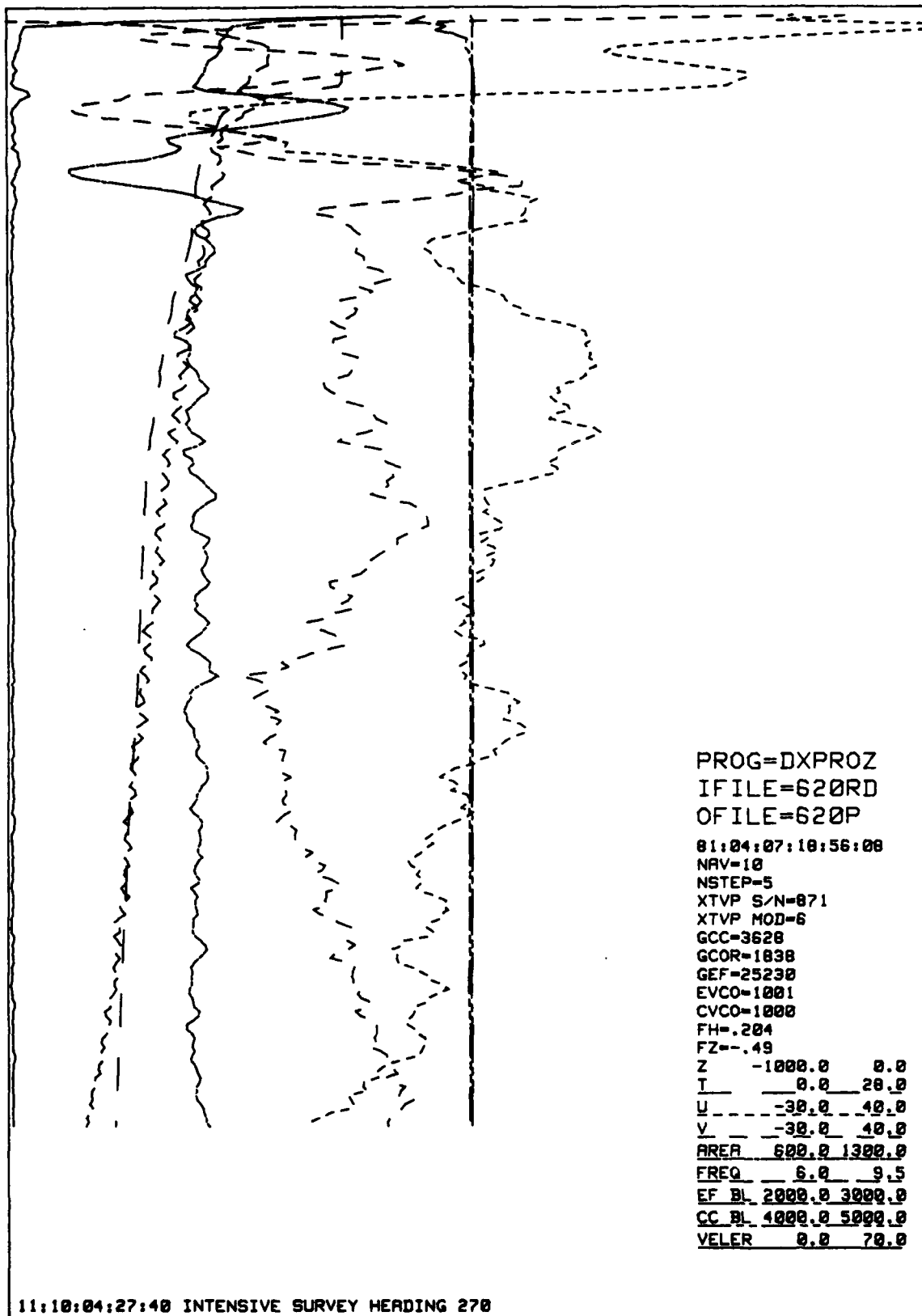
24.29 -6.2 2450 4484

425.722796875 2D.D

MEAN AREA= 745 cm^2

Z-1000 0

ENTER NEW PLOT LIMITS: PLO, PHI



PROG=DXPROZ
IFILE=620RD
OFIL=620P
01:04:07:10:56:00
NAV=10
NSTEP=5
XTVP S/N=871
XTVP MOD=6
GCC=3628
GCOR=1838
GEF=25230
EVCO=1001
CVCO=1000
FH=.204
FZ=-.49
Z -1000.0 0.0
T 0.0 28.0
U -30.0 40.0
V -30.0 40.0
AREA 600.0 1300.0
FREQ 6.0 9.5
EF BL 2000.0 3000.0
CC BL 4000.0 5000.0
VELER 0.0 70.0

Listing of DXPRO

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10 Progrev$="DXPROZ" ! PROGRAM REVISION
20 Year=81
30 !
40 ! DXPRO .. DEC 19 79. DIGITAL XTVP RCVR PROCESSING (see outline below)
50 ! DXPROB .. DEC 21 79. BARTLETT WINDOWS; INSTANTANEOUS NORMALIZATION.
60 ! DXPROC .. JAN 13 80. CORRECTED I & Q OF EF & CC FOR DIFF UP & DOWN COUNT
TIMES
70 ! DXPROD .. JAN 14 80. ALLOW FOR RCVR HICCUPS AND DE-GLITCH I&Q
80 ! DXPROE .. JAN 15 80. FORCE TIME TO INCREASE AFTER PF COMES ON FOR 5 TURN
S
90 ! DXPROF .. JAN 16 80. PROCESS ONLY. TO GET DATA USE DXGET.
100 ! DXPROG .. JAN 17 80. INTERPOLATE TO EQUALLY SPACED DEPTH AND OUTPUT FILE
110 ! DXPROH .. JAN 25 80. MORE INFO TO GET TO SCAN WHERE PROBE FALLS
120 ! DXPROI .. MAR 9 80. PROCESS BASELINE INFO. SIGN OF Q FROM RCVR CHANGED.
130 ! DXPROJ .. MAR 11 80. PLOT EF&CC BL.
140 ! DXPROK .. MAR 19 80. MORE TESTS.
150 ! DXPROL .. MAR 24 80. PLOT BL AVGS AND STD DEV
160 ! DXPROM .. MAR 25 80. PLOT RMSERR
170 ! DXPRON .. MAR 25 80. RMSERR SHOWS DIFF BETWEEN ERRCOR=3 AND ERRCOR=1
180 ! DXPROP .. MAR 28 80. RMSERR FROM RMS OF DATA.
190 ! DXPROR .. APR 29 80. MODIFIED TO OUTPUT NEW FILE FORMAT AND USE GRAPHICS
200 ! DXPROS .. MAY 6 80. SPEEDED UP DXPROR BY ONLY CORRECTING NEW DATA
210 ! DXPROT .. JUN 17 80. CHANGED RMSERR TO VELERR=RMSERR/SQR(NAV)
220 ! DXPROV .. JUL 31 80. ADDED "BATCH" CAPABILITY.
230 ! DXPROW .. AUG 5 80. ADDED 9872S LOGIC FOR BATCH.
240 ! .. OCT 31 80. REMOVED PAUSE BEFORE PLOTTING ON 9872A.
250 ! AND CHANGED CAL FILE TO BE ON :T15
260 ! DXPROX .. NOV 19 80. FIXED PROBLEMS WITH COMPENSATION
270 ! DXPROW AND PREVIOUS DID NOT HANDLE PROBE PHASES CORRECTLY
280 ! THE PROBE PHASE VS FREQ COEFFICIENTS ARE ALSO ADDED.
290 !
300 ! DXPROY .. JAN 28 81. ADDED COMMENTS. JHD.
310 ! DXPROZ .. MAR 31 81. ADDED D'ASARO TILT CORRECTION. JHD.
320 !
330 ! OUTLINE .....
340 ! Initialization
350 ! - print program name ,revision and run time
360 ! - dimension arrays
370 ! - read in processing parameters for up to 100 drops; terminate when
380 ! an input file name is blank.
390 ! - get parameter file name with probe gain calibrations.
400 ! - use serial number of drop i.d. to search parameter file for gains.
410 ! - calibration string can be edited.
420 ! - must add the earth's magnetic field if not in file
430 ! - the plotter choice allows the 9872A only when one file is processed
440 ! Drop loop: repeats once per drop
450 ! - some constants are preset to reduce run time.
460 ! Main Processing Loop.
470 ! - repeats once each NAV-long averaging window.
480 ! - For NAV=10, NSTEP=5 this loop repeats about 300 times.
490 ! - read raw input data keeping in sync with the sync word (7777 hex)
500 ! - look for beginning of drop by examining status word:
510 ! 1. received carriers
520 ! 2. probe falling bit (PF)
530 ! - probe depth is based on the time from the PF bit turns on.

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540 ! - for each new raw data scan the baseline error correction is
550 !   applied to I and Q and the scan is appended to the Dbuf(*) array.
560 ! - old scans are pushed off end of Dbuf(*) array
570 ! - form Dav(*) array with weighted averages of Dbuf(*).
580 ! - in-phase and quadrature-phase probe carrier frequencies are computed
590 ! - real and imaginary input voltages to probe are computed.
600 ! - U and V velocity component estimates are computed. tilt correction
610 !   is done in next loop as mean area is needed.
620 ! - each output scan is stored in Dout(*) array.
630 ! Correct the north component for North-South tilt errors
640 !   - need mean area
650 !   - fix the Dout(*) array
660 ! Write Data in Dout(*) to File.
670 !   - standardized format with labels
680 ! Plot Data on 9872A, 9872S, or GRAPHICS screen.
690 !   - the 9872S handles multiple plots
700 !   - keep to 8.5 by 11 inch plots
710 !   - all graphs on one sheet in multiple colors
720 ! Repeat drop loop
730 !
740 Printer=0
750 PRINTER IS Printer
760 !
770 OUTPUT 9;"R"          ! SETUP TO GET REAL-TIME FROM CLOCK
780 ENTER 9;Runtime$      ! GET IT
790 Runtime$=VAL$(Year)&":"&Runtime$
800 PRINT Progrev$,Runtime$
810 !
820 OPTION BASE 1        ! STARTS ARRAYS AT 1 INSTEAD OF DEFAULT 0
830 OVERLAP              ! RUN HP-9845 PROCESSORS SO I/O OVERLAPS CPU
840 DEG                 ! TRIG FUNCTIONS USE DEGREES INSTEAD OF RADIANS
850 !
860 DIM Comment$(160)    ! COMMENTS FROM/TO FILES
870 DIM Var$(9)         ! OUTPUT FILE VARIABLE NAMES
880 DIM String$(160)    ! USED TO READ PARAMETER FILE
890 !
900 SHORT Din(2:11)     ! INPUT DATA BUFFER READS 10 VALUES PER READ
910 SHORT Dbuf(52,2:10) ! PUSH-DOWN INPUT BUFFER WITH EXTRA SCAN AT EACH END
920                   ! NEEDED FOR BASELINE ERROR CORRECTION.
930 SHORT Wt(50)        ! BARTLETT FILTER WEIGHTS APPLIED TO INPUT DATA
940 SHORT Dav(2:10)     ! FOR DOT PRODUCT OF DBUF AND WT
950 !
960 SHORT Phi(9)        ! PLOTTER HIGH LIMITS
970 SHORT Plo(9)        ! PLOTTER LOW LIMITS
980 SHORT Dout(1000,9)  ! DATA OUTPUT ARRAY (GETS REDIMENSIONED LATER)
990 !
1000 DIM B3(3),B2(3)    ! BASELINE FREQUENCIES FOR F2(EF) AND F3(CC)
1010 DIM T(3,3)         ! COEFFICIENTS OF C, D & E IN B(n-1), B(n), B(n+1)
1020 DIM Tinu(3,3)      ! INVERSE OF T ABOVE TO SOLVE FOR C, D & E.
1030 DIM C2(3),C3(3)    ! C2(1)=C, C2(2)=D, C2(3)=E FOR F2(EF); C3(*) FOR F3.
1040 DIM Tei(3),Teq(3)  ! COEFFICIENTS OF C, D & E IN I(n) AND Q(n)
1050 !
1060 Nvar=10             ! NUMBER OF INPUT VARIABLES
1070 Max=50              ! MAXIMUM AVERAGING SPAN (NAV). MUST AGREE WITH DIM
1080                   ! OF DBUF,WT.
1090 Msout=1000         ! MAXIMUM SCANS OUT. MUST AGREE WITH DIM OF DOUT.

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1100 Nvout=9          ! MAXIMUM VARIABLES OUT. MUST AGREE WITH DIM OF DOUT,
1110                  ! PHI,PLO,VAR$
1120 Bad=0           ! FLAG USED FOR BAD DATA OUT
1130 !
1140 ! SETUP FOR MULTIPLE INPUT FILE PROCESSING.
1150 !
1160 DIM Ifile$(100)  ! INPUT FILE NAMES
1170 DIM Ofile$(100)  ! OUTPUT FILE NAMES
1180 DIM Nav(100)     ! NUMBER OF SCANS TO AVERAGE
1190 DIM Nstep(100)   ! NUMBER OF SCANS TO STEP THE AVERAGES BY; USUALLY
1200                  ! AVERAGES ARE OVERLAPPED 50% OR SO
1210 DIM String$(100)[80] ! CALIBRATION CONSTANTS FROM THE XCAL FILE FOR EACH
1220                  ! FILE
1230 DIM Comment$(100)[160] ! COMMENTS FROM EACH INPUT FILE.
1240 !
1250 FOR File=1 TO 100
1260   DISP "INPUT FILE NO. ";File;"? (CLEAR TO TERMINATE)";
1270   EDIT " ",Ifile$(File)
1280   Ifile$=Ifile$(File)
1290   IF LEN(Ifile$)=0 THEN 2070
1300 !
1310   ASSIGN #1 TO Ifile$,Ret
1320   IF Ret=0 THEN 1350
1330   DISP "FILE NOT ON PRESENT DISC. ";
1340   GOTO 1260
1350 !
1360   READ #1;Comment$(File)
1370 !
1380   EDIT "EDIT COMMENTS",Comment$(File)
1390 !
1400   INPUT "NUMBER OF SCANS IN EACH AVERAGING WINDOW ?",Nav(File)
1410   Nav=Nav(File)
1420   IF Nav>Max THEN 1400 ! RESTRICT NAV TO MAX
1430 !
1440   INPUT "STEPPING INCREMENT?",Nstep(File)
1450   Nstep=Nstep(File)
1460 !
1470   IF LEN(Pfile$)=0 THEN Pfile$="XCAL :T15"
1480   EDIT "EDIT calibration file name. (BLANK TO ENTER CAL BY HAND)",Pfile$
1490   IF LEN(Pfile$)=0 THEN 1720
1500 !
1510   INPUT "XTVP SERIAL NO. ? (ZERO TO SEARCH BY DROP NO.)",Serial
1520 !
1530   IF Serial=0 THEN INPUT "Drop ID.?",Dropid$
1540 !
1550   ASSIGN #3 TO Pfile$,Ret ! ASSIGN UNIT NUMBER TO PARAMETER FILE NAME
1560   IF Ret<>0 THEN 1480      ! Ret SHOULD BE 0 IF FILE IS THERE
1570   READ #3,1                ! REWIND FILE
1580   ON END #3 GOTO 1890       ! SET UP END OF FILE TRAP
1590   DISP "READING ";Pfile$
1600 !
1610 ! READ EACH STRING IN THE PARAMETER FILE SEARCHING FOR THE DROP ID
1620 ! OR SERIAL NUMBER.
1630 !
1640   READ #3;String$
1650   IF LEN(String$)<58 THEN String$=String$&RPT$(" ",58-LEN(String$))

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1660 IF (Serial<>0) AND (VAL(String$[8,12])=Serial) THEN 1720
1670 IF (Serial=0) AND (TRIM$(String$[44,48])=TRIM$(Dropid$)) THEN 1720
1680 GOTO 1640
1690 !
1700 ! EDIT/ENTER THE CALIBRATION STRING. THERE MUST BE A VALUE IN EACH FIELD
1710 !
1720 ! EDIT "EDIT: Probe Mod Gcc Gcor Gef Evco Cvco Drop Fh Fz",String$
1730 GOTO 1830
1740 !
1750 IF ERRN=159 THEN 1870
1760 DISP ERRM$
1770 PAUSE
1780 GOTO 1860
1790 !
1800 ! DECODE THE CALIBRATION STRING WITH ERROR CHECKING AND TRAPPING
1810 ! TO CHECK THAT IT WILL DECODE WHILE PROCESSING WITHOUT HALTING.
1820 !
1830 ON ERROR GOTO 1750
1840 ENTER String$ USING 1850;Probe,Mod,Gcc,Gcor,Gef,Efuf,Ccvf,Drop$,Fh,Fz
1850 IMAGE #,7X,4<5N>,6N,2<5N>,5A,2<5N>
1860 OFF ERROR
1870 GOTO 1940
1880 !
1890 BEEP
1900 DISP "CANNOT FIND THE CALIBRATION STRING. "
1910 WAIT 3000
1920 GOTO 1230
1930 !
1940 ASSIGN #3 TO * ! UNASSIGN UNIT 3; PFILE$ IS NOT ASSIGNED.
1950 String$(File)=String$
1960 !
1970 EDIT "OUTPUT FILE NAME?",Ofile$(File)
1980 Ofile$=Ofile$(File)
1990 !
2000 IF LEN(Ofile$)=0 THEN 1940
2010 ASSIGN #2 TO Ofile$,Ret ! CHECK TO SEE IF OUTPUT FILE ALREADY EXISTS;
2020 IF Ret=1 THEN 2050 ! FORCE USER TO USE ANOTHER NAME IF IT DOES.
2030 DISP "ALREADY EXISTS -- CHOOSE ANOTHER NAME";
2040 GOTO 1970
2050 !
2060 NEXT File ! END OF PARAMETER INPUT *****
2070 !
2080 Nfile=File-1 ! NUMBER OF INPUT FILES TO PROCESS
2090 !
2100 ! CANNOT USE THE 9872A PLOTTER WITH MULTIPLE FILE PROCESSING BECAUSE
2110 ! THERE IS NO AUTOMATIC PAPER FEED.
2120 !
2130 IF Nfile>1 THEN INPUT "PLOTTER ? (0=NONE, 1=GRAPHICS, 3=9872S)",Plotter
2140 IF Nfile=1 THEN INPUT "PLOTTER ? (0=NONE, 1=GRAPHICS, 2=9872A, 3=9872S)",Plotter
2150 IF (Plotter<0) OR (Plotter>3) THEN 2130
2160 IF (Nfile>1) AND (Plotter=2) THEN 2130
2170 !
2180 ! ACTUAL PROCESSING STARTS HERE AND REQUIRES NO MORE OPERATOR RESPONSES.
2190 !

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```

2200 FOR File=1 TO Nfile
2210   String$=String$(File)
2220   ! CALIBRATION CONSTANTS DECODED FOR USE
2230   ENTER String$ USING 1850;Probe,Mod,Gcc,Gcor,Gef,Efuf,Ccuf,Drop$,Fh,Fz
2240   !
2250   Ifile$=Ifile$(File)
2260   Ofile$=Ofile$(File)
2270   Nav=Nav(File)
2280   Nstep=Nstep(File)
2290   !
2300   ASSIGN #1 TO Ifile$   ! ASSUMES IFILE$ IS PRESENT BECAUSE CHECKED BEFORE
2310   READ #1,1
2320   READ #1;Comment$      ! INPUT DATA IS ONE COMMENT$ STRING FOLLOWED BY
2330                           ! DIGITAL RECEIVER DATA NUMERIC VALUES.
2340   REDIM Dout(Msout,9)   ! SET DOUT TO MAX SIZE AFTER PREVIOUS FILES USE
2350   !
2360   ON Mod-3 GOTO 2430,2480,2530
2370   ! PROBE PHASE FROM CIRCUIT ANALYSIS DEPENDS ON MODEL NUMBER.
2380   ! ART BARTLETT AT W.H.O.I. MADE MOD 4.
2390   ! SIPPICAN MANUFACTURED MOD 5 ONLY FOR TOM SANFORD AT W.H.O.I. IN
2400   ! MAY 1979.
2410   ! SIPPICAN MANUFACTURED MOD 6 AFTER JULY 1979.
2420   !
2430   Gefp=15.2             ! XTVP MOD 4 (WHOI/BARTLETT-MADE)
2440   Gcorp=-165.1
2450   Gccp=-179.0
2460   GOTO 2680
2470   !
2480   Gefp=10.9            ! XTVP MOD 5 (SIPPICAN-MADE FOR AUTEC WORK ONLY)
2490   Gcorp=-169.3
2500   Gccp=-177.7
2510   GOTO 2680
2520   !
2530   Gefp=15.2            ! XTVP MOD 6 (SIPPICAN-MADE AFTER JULY 1979)
2540   Gcorp=-165.1
2550   Gccp=-179.0
2560   !
2570   Gefp0=45.77142872   ! QUADRATIC FITS VS ROTATION FREQUENCY
2580   Gefp1=-6.29750005   ! DETERMINED ANALYTICALLY FOR MOD 6 PROBES
2590   Gefp2=.276785719
2600   !
2610   Gcorp0=-133.4857151
2620   Gcorp1=-6.5403571
2630   Gcorp2=.29107141
2640   !
2650   Gccp0=-176.0285726
2660   Gccp1=-.5978569
2670   Gccp2=.02499997
2680   ! CONVERT TO NEW LINGO
2690   Gcora=Gcor
2700   Gcca=Gcc
2710   Gefa=Gef
2720   Geufa=Efuf
2730   Gcufa=Ccuf
2740   Gevfp=0
2750   Gcufp=0

```

```

2760 |
2770 | Esep=5.12      !cm      ! PROBE PHYSICAL PARAMETERS
2780 | C1=.97
2790 | C2=-.02
2800 |
2810 | DATA .00129299,.00023488,.980557E-7      ! CAL FOR SIPPICAN THERMISTOR
2820 | RESTORE 2810
2830 | READ Tecala,Tecalb,Tecalc      ! PUT ABOVE DATA IN TECALA,B,C
2840 |
2850 | DATA -11336.3,7302.0      ! TEMP RESISTANCE VS MS
2860 | RESTORE 2850
2870 | READ Teres0,Teres1      ! PUT ABOVE DATA IN TERES0,1
2880 |
2890 | DATA 3.1,4.544,-.0006749      ! PRESSURE VS TIME CAL
2900 | RESTORE 2890
2910 | READ Pcal0,Pcal1,Pcal2      ! PUT ABOVE DATA IN PCAL0,1,2
2920 |
2930 | RCVR SCALE FACTORS FOR EACH FREQUENCY CHANNEL:
2940 |
2950 | S1=1/200      ! S1,S2,S3 ARE INVERSE OF PHASE LOCK LOOP
2960 | S2=1/40      ! MULTIPLICATION FACTORS.
2970 | S3=1/20
2980 |
2990 | Sff2=2*PI/4*S2      ! SFF2,3 ARE SCALE FACTORS TO CONVERT I & Q
3000 | Sff3=2*PI/4*S3      ! TO THE AMPLITUDE OF THE FREQUENCY DEVIATIONS.
3010 |
3020 | Sffe=Sff2      ! FOR MOD 5 PROBES F3 WAS EF AND F2 WAS CC
3030 | IF Mod=5 THEN Sffe=Sff3      ! FOR ALL OTHERS F3=CC AND F2=EF
3040 |
3050 | Sfv=100/Fz/Esep/(1+C1)      ! SCALE FACTOR OF VELOCITY FROM EF
3060 | Sfw=Fh/Fz*(1+C2)/(1+C1)      ! SCALE FACTOR OF Uw FROM W
3070 | Sfa=100/2/PI/Fh      ! SCALE FACTOR FOR AREA FROM VC0/FREQ
3080 |
3090 | REDIM Wt(Nav)      ! BARTLETT WINDOW FOR FILTERING
3100 | FOR I=1 TO (Nav+1) DIV 2      ! (TRIANGULAR WINDOW, SUM NORMALIZED TO 1.0)
3110 | Wt(I)=Wt(Nav+1-I)=I
3120 | NEXT I
3130 | MAT Wt=Wt/(SUM(Wt))
3140 |
3150 | Sync=30583      ! SYNC WORD EXPECTED FROM DIGITAL RECEIVER
3160 |
3170 | Mastertime$=Comment$(1,18)      ! REAL-TIME WHEN DXGET WAS RUN
3180 |
3190 | Oscan=Iscan=Nhave=Fallng=Time=Mastertime=Launchtime=0
3200 |
3210 | Nwant=Nav+2      ! WANT THE INPUT BUFFER TO OVERLAP A VALUE ON EACH END
3220 |
3230 | MAT Dout=(Bad)      ! INITIALIZE THE OUTPUT DATA ARRAY
3240 |
3250 | DISP "LOOKING FOR PF ON"
3260 |
3270 | Mainloop:      ! MAINLOOP
3280 |   Npush=Nstep
3290 |   Coll$=""
3300 |
3310 | Pushdown:      ! PUSHDOWN DBUF(*) BY NSTEP SCANS

```

```

3320 REDIM Dbuf(1:Nwant,2:Nvar)
3330 IF Npush<Nhave THEN 3360
3340 Nhave=0
3350 GOTO Getmore
3360 FOR I=Npush+1 TO Nhave
3370 J=I-Npush
3380 FOR L=2 TO Nvar
3390 Dbuf(J,L)=Dbuf(I,L)
3400 NEXT L
3410 NEXT I
3420 Nhave=Nhave-Npush
3430 !
3440 Getmore: ! GETMORE KEEPING IN SYNC.
3450 ! EARLY VERSIONS OF THE DIGITAL RECEIVER WOULD GIVE DATA
3460 ! TOO FAST FOR DXGET AND THUS WOULD GET OUT OF SYNC
3470 READ #1;Din(*) ! READ ONE INPUT SCAN AT A TIME UNLESS LOSE SYNC
3480 ! THEN READ ONE VALUE AT A TIME UNTIL SYNC'D AGAIN
3490 IF (Din(2)<>Sync) AND (Din(11)=Sync) THEN 3590
3500 IF Iscan>0 THEN PRINT "LOST SYNC BEFORE ISCAN=";IsCAN
3510 Din0=Din(2)
3520 FOR I=2 TO Nvar
3530 Din(I)=Din(I+1)
3540 NEXT I
3550 READ #1;Din(Nvar+1)
3560 IF Din0<>Sync THEN 3510
3570 GOTO 3490
3580 !
3590 Iscan=IsCAN+1
3600 Mastertime=Mastertime+Din(4)*1E-5
3610 ! PRINT USING "11(7D)";IsCAN,Din(*) ! DEBUGGING PRINT
3620 ! TEST STATUS WORD
3630 Status=Din(2)
3640 ! THE NUMBER OF WORDS TAKEN IN THE LAST SCAN IS ENCODED IN BITS 11-8
3650 IF (SHIFT(Status,8)<>Nvar) AND (IsCAN>1) THEN PRINT "MISSED SCAN(S) FROM
DR AT ISCAN=";IsCAN
3660 ! BITS 2-0 INDICATE IF THE CARRIERS ARE PRESENT LIKE THE LIGHTS ON PANEL.
3670 ! WHEN THE PROBE IS LAUNCHED THE CARRIERS SHOULD ALL COME ON
3680 IF Launchtime OR NOT BIT(Status,"111") THEN 3740
3690 Launchtime=Mastertime
3700 CALL Addtime(Mastertime$,Launchtime$,Launchtime)
3710 PRINT "LAUNCH-TIME=",Launchtime$,Launchtime,"ISCAN=";IsCAN
3720 ! BIT 3 OF STATUS SHOWS THE PF LIGHT ON PANEL. IT IS ON WHEN THE CC
3730 ! CHANNEL DEVIATES MORE THAN A PRE-SET THRESHHOLD.
3740 IF NOT Falling AND (BIT(Status,3)=0) THEN Getmore
3750 ! TRANSFER FROM DIN TO DUF
3760 Nhave=Nhave+1
3770 FOR L=2 TO Nvar
3780 Dbuf(Nhave,L)=Din(L)
3790 NEXT L
3800 IF Nhave<Nwant THEN Getmore
3810 !
3820 REDIM Dbuf(0:Nwant-1,2:Nvar)
3830 ! USE PROBE FALLING (PF) BIT TO START AND STOP PROCESSING:
3840 Npf=0 ! WANT NPF=NAV TO START PROCESSING
3850 FOR I=1 TO Nav ! ALLOW NPF<NAV TO STOP PROCESSING WHEN TIME>200 SEC
3860 Npf=Npf+BIT(Dbuf(I,2),3)

```

```

3870 NEXT I
3880 IF Falling OR (Npf=Nav) THEN 3910
3890 Npush=1
3900 GOTO Pushdown
3910 IF (Time>200) AND (Npf<Nav) THEN Endloop
3920 IF Npf=0 THEN Endloop
3930 IF Falling THEN 4000
3940 Falling=1
3950 Downtime=Mastertime
3960 CALL Addtime(Mastertime$,Downtime$,Downtime)
3970 PRINT "DOWN-TIME=",Downtime$,Downtime,"ISCAN=";Iscan-Nwant+1
3980 DISP "PROCESSING FILE ";File;". IFILE=";Ifile;". OFILE=";Ofile$
3990 !
4000 ! COMPUTE THE ERROR TERMS IN I AND Q THEN CORRECT DBUF FOR NEW SCANS
4010 ! (THE OLD SCANS WERE CORRECTED ALREADY BECAUSE DBUF WAS PUSHED DOWN)
4020 !
4030 J1=Nhave-Npush-1
4040 IF Oscan>0 THEN 4160
4050 J1=1
4060 ! T1 = T(n-1) in report
4070 ! T2 = T(n)
4080 ! T3 = T(n+1)
4090 T11=Dbuf(J1-1,4)*1E-5 ! T11 IS T1
4100 T12=T11*T11 ! T12 IS T1 SQUARED
4110 T13=T12*T11 ! T13 IS T1 CUBED
4120 T21=Dbuf(J1,4)*1E-5
4130 T22=T21*T21
4140 T23=T22*T21
4150 D3=1/3
4160 J2=Nav
4170 FOR J=J1 TO J2
4180 I=J-1
4190 K=J+1
4200 T31=Dbuf(K,4)*1E-5
4210 T32=T31*T31
4220 T33=T32*T31
4230 T(1,1)=T11 ! SET UP T(*) TO SOLVE FOR C,D,E GIVEN B1,B2,B3.
4240 T(1,2)=-.5*T12 ! C,D,E ARE COMPUTED IN C2(*) AND C3(*) FOR
4250 T(1,3)=D3*T13 ! EF AND CC RESPECTIVELY.
4260 T(2,1)=T21
4270 T(2,2)=-.5*T22
4280 T(2,3)=D3*T23
4290 T(3,1)=T31
4300 T(3,2)=T21*T31+.5*T32
4310 T(3,3)=T22*T31+T21*T32+D3*T33
4320 MAT Tinu=INV(T)
4330 B3(1)=Dbuf(I,7)
4340 B2(1)=Dbuf(I,8)
4350 B3(2)=Dbuf(J,7)
4360 B2(2)=Dbuf(J,8)
4370 B3(3)=Dbuf(K,7)
4380 B2(3)=Dbuf(K,8)
4390 MAT C3=Tinu*B3 ! C3(*)=C,D,E FOR COIL CHANNEL
4400 MAT C2=Tinu*B2 ! C2(*)=C,D,E FOR EF CHANNEL
4410 Tei(1)=T11-T21
4420 Tei(2)=-.25*T12-.5*T22

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4430      Tei(3)=T13/12-T23/3
4440      Teq(1)=1.25*(T11-T21)
4450      Teq(2)=(17*T12-25*T22)/32
4460      Teq(3)=(53*T13-125*T23)/192
4470      Ei3=DOT(Tei,C3)      ! COMPUTE I AND Q ERRORS FOR EF AND CC
4480      Ei2=DOT(Tei,C2)
4490      Eq3=DOT(Teq,C3)
4500      Eq2=DOT(Teq,C2)
4510      ! debugging printout
4520      IF NOT Debugging THEN 4580
4530      IF J=J1 THEN PRINT LIN(1);" ISCAN STATUS      TEMP PERIOD      Icc      I
ef      BLcc      BLef      Qcc      Qef"
4540      PRINT USING 4550;Iscan-Nwant+J,Dbuf(J,2),Dbuf(J,3),Dbuf(J,4),Dbuf(
J,5),Dbuf(J,6),Dbuf(J,7),Dbuf(J,8),Dbuf(J,9),Dbuf(J,10)
4550      IMAGE 6D,9(7D)
4560      PRINT USING 4570;Ei3,Ei2,Eq3,Eq2
4570      IMAGE 14X,"I & Q ERRORS:",7D,7D,14X,7D,7D
4580      Dbuf(J,5)=Dbuf(J,5)-Ei3      ! SUBTRACT ERRORS FROM DBUF
4590      Dbuf(J,6)=Dbuf(J,6)-Ei2
4600      Dbuf(J,9)=Dbuf(J,9)-Eq3
4610      Dbuf(J,10)=Dbuf(J,10)-Eq2
4620      IF NOT Debugging THEN 4650
4630      PRINT USING 4640;Dbuf(J,5),Dbuf(J,6),Dbuf(J,9),Dbuf(J,10)
4640      IMAGE 13X,"I & Q RESULTS:",7D,7D,14X,7D,7D
4650      T11=T21      ! PUSH DOWN SOME STUFF TO SPEED PROCESSING
4660      T12=T22      ! INSTEAD OF RECOMPUTING
4670      T13=T23
4680      T21=T31
4690      T22=T32
4700      T23=T33
4710      NEXT J
4720      !
4730      ! NORMALIZE THE DBUF DATA TO GET THE FREQUENCY AMPLITUDES OF THE PROBE.
4740      ! APPLY THE BARTLETT FILTERING WINDOW TO DBUF(*).
4750      !
4760      MAT Dav=ZER
4770      Eis=Eiss=Eqs=Eqss=0
4780      !
4790      FOR J=1 TO Nav
4800          Wt=Wt(J)
4810          T1=Dbuf(J-1,4)*1E-5
4820          T2=Dbuf(J,4)*1E-5
4830          Dt=Dbuf(J,4)-Dbuf(J-1,4)
4840          Rfi=1/T2
4850          Rfq=1/(1.25*T2-.25*T1)
4860          Wtri=Wt*Rfi
4870          Wtrq=Wt*Rfq
4880          Dav(3)=Dav(3)+Dbuf(J,3)*Wtri
4890          Dav(4)=Dav(4)+Dbuf(J,4)*Wt
4900          Dav(7)=Dav(7)+Dbuf(J,7)*Wtri
4910          Dav(8)=Dav(8)+Dbuf(J,8)*Wtri
4920          Dav(5)=Dav(5)+Dbuf(J,5)*Wtri
4930          Dav(6)=Dav(6)+Dbuf(J,6)*Wtri
4940          Dav(9)=Dav(9)+Dbuf(J,9)*Wtrq
4950          Dav(10)=Dav(10)+Dbuf(J,10)*Wtrq
4960      ! SUMS AND SUMS OF SQUARES TO COMPUTE RMS ERR

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```

4970      IF Mod=5 THEN 5050
4980      Ei=Dbuf(J,6)*Rfi
4990      Eq=Dbuf(J,10)*Rfq
5000      Eis=Eis+Ei
5010      Eiss=Eiss+Ei^2
5020      Eqs=Eqs+Eq
5030      Eqss=Eqss+Eq^2
5040      GOTO 5110
5050      Ei=Dbuf(J,5)*Rfi
5060      Eq=Dbuf(J,9)*Rfq
5070      Eis=Eis+Ei
5080      Eiss=Eiss+Ei^2
5090      Eqs=Eqs+Eq
5100      Eqss=Eqss+Eq^2
5110      !
5120      NEXT J
5130      !
5140      Rotp=Daυ(4)*1E-5
5150      Rotf=1/Rotp
5160      ! TIME IS COMPUTED BY SUMMING ALL THE PERIODS SINCE THE PROBE STARTED DOWN
5170      IF Oscan=0 THEN Time=Rotp*(Nav/2-Nstep)
5180      Time=Time+Nstep*Rotp
5190      !
5200      F1b=Daυ(3)*S1
5210      F2i=Daυ(6)*Sff2
5220      F2q=Daυ(10)*Sff2
5230      F2b=Daυ(8)*S2
5240      F3i=Daυ(5)*Sff3
5250      F3q=Daυ(9)*Sff3
5260      F3b=Daυ(7)*S3
5270      !
5280      IF Mod=5 THEN 5360
5290      Fcci=F3i
5300      Fccq=F3q
5310      Fccb=F3b
5320      Fefi=F2i
5330      Fefq=F2q
5340      Fefb=F2b
5350      GOTO 5420
5360      Fcci=F2i
5370      Fccq=F2q
5380      Fccb=F2b
5390      Fefi=F3i
5400      Fefq=F3q
5410      Fefb=F3b
5420      !
5430      Tems=1000/F1b
5440      Teres=Teress0+Teress1*Tems
5450      IF Teres>0 THEN 5480
5460      Temp=Bad
5470      GOTO 5560
5480      Ln=LOG(Teres)
5490      Temp=1/(Tecal1+Tecal2*Ln+Tecal3*Ln^3)-273.15
5500      !
5510      R1=Rotf
5520      R2=Rotf^2

```

ROTATION FREQ AND PERIOD

PROBE CARRIER FREQUENCIES

PUT CARRIER FREQ'S IN PROPER VARIABLES

TEMPERATURE

! PERIOD IN MILLISECONDS OF TEMPERATURE CARRIER

! THERMISTOR RESISTANCE

! DEGREES C

PROBE PHASES VS ROTATION FREQ USING QUADRATIC ESTIMATES

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5530 Gefp=Gefp0+Gefp1*R1+Gefp2*R2
5540 Gcorp=Gcorp0+Gcorp1*R1+Gcorp2*R2
5550 Gccp=Gccp0+Gccp1*R1+Gccp2*R2
5560 ! COIL MICROVOLTS
5570 CALL Polar(-Fccq,-Fcci,Fcca,Fccp)
5580 Vc0a=Fcca/Gcvfa/Gcca*1E6 ! Eca in report
5590 Vc0p=Fccp-Gcvfp-Gccp ! Ecp in report
5600 ! ELECTRODE MICROVOLTS
5610 CALL Polar(-Fefq,-Fefi,Fefa,Fefp)
5620 Ve0a1=Fefa/Geufa/Gefa*1E6
5630 Ve0p1=Fefp-Geufp-Gefp
5640 CALL Rect(Ve0a1,Ve0p1,Ve0q1,Ve0i1)
5650 Ve0a2=Fcca/Gcvfa/Gcca*Gcora/Gefa*1E6
5660 Ve0p2=Fccp-Gcvfp-Gccp+Gcorp-Gefp
5670 CALL Rect(Ve0a2,Ve0p2,Ve0q2,Ve0i2)
5680 Ve0q=Ve0q1-Ve0q2
5690 Ve0i=Ve0i1-Ve0i2
5700 CALL Polar(Ve0q,Ve0i,Ve0a,Ve0p) ! Ve0a is Eea in report
5710 ! Ve0p is Eep in report
5720 ! FALL RATE, PRESSURE, Z=-PRESSURE
5730 W=-100*(Pcal1+2*Pcal2*Time) ! empirically determined pressure vs time
5740 P=Pcal0+Time*(Pcal1+Time*Pcal2)
5750 Z=-P
5760 ! AREA OF COIL TIMES TURNS (cm^2)
5770 Area=Vc0a/Rotf*Sfa
5780 ! PHASE OF ZERO CROSSING DETECTOR circuit
5790 Zcdp=-90-Fccp
5800 ! VELOCITY COMPENSATION
5810 Uw=W*Sfw ! LIKE EMVP REPORT
5820 Betae=-Ve0p ! Ve0p and Vc0p phases have signs so if the signal leads
5830 Betac=-Vc0p ! the phases are positive. Betae and Betac are opposite.
5840 Alpha=180 ! angle from electrode to coil
5850 Psi=Betae-Betac+90+Alpha ! see EMVP report
5860 U=Ve0a*Sfu*COS(Psi)
5870 V=-Ve0a*Sfu*SIN(Psi)+Uw
5880 !
5890 Sfef=1E6/Gefa/Geufa
5900 Rmserr=SQRT(.5*(Eiss/Nav-(Eis/Nav)^2+Eqss/Nav-(Eqc/Nav)^2))*ABS(Sffe*Sfef
5910 *Sfu)
5910 Velerr=Rmserr/SQRT(Nav) ! normalize rmserr
5920 ! PRINT
5930 IF Debugging OR (Oscan MOD 20=0) THEN PRINT USING 5940
5940 IMAGE " Z Temp U V W Rotf Area Uw Vc0a Zcdp Ve0a Ve0p
Fefb Fccb Ver"
5950 PRINT USING 5960;Z,Temp,U,V,W,Rotf,Area,Uw,Vc0a,Zcdp,Ve0a,Ve0p,Fefb,Fccb
,Velerr
5960 IMAGE 4D,3D.2D,2 (4D.D),5D,2D.2D,3(5D),3D.D,3D.2D,4D.D,2(5D),2D.D
5970 !
5980 Oscan=Oscan+1
5990 Dout(Oscan,1)=Z ! STORE IN OUTPUT ARRAYS
6000 Dout(Oscan,2)=Temp
6010 Dout(Oscan,3)=U
6020 Dout(Oscan,4)=V
6030 Dout(Oscan,5)=Area
6040 Dout(Oscan,6)=Rotf
6050 Dout(Oscan,7)=Fefb

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6060      Dout(Oscan,8)=Fccb
6070      Dout(Oscan,9)=Velerr
6080      !
6090      IF Oscan<Msout THEN Mainloop
6100      !
6110      Endloop: !
6120      !
6130      Nsout=Oscan-3
6140      REDIM Dout(Nsout,Nvout)
6150      !
6160      ! CORRECT FOR NORTH-SOUTH TILTS A LA D'ASARO
6170      Velerrmax=4
6180      Na=0
6190      Amean=0
6200      FOR Oscan=1 TO Nsout
6210          Velerr=Dout(Oscan,9)
6220          IF Velerr>Velerrmax THEN 6260
6230              Area=Dout(Oscan,5)
6240              Amean=Amean+Area
6250              Na=Na+1
6260      NEXT Oscan
6270      !
6280      Amean=Amean/Na
6290      PRINT USING "K,5D,K";"MEAN AREA=",Amean," cm^2"
6300      !
6310      FOR Oscan=1 TO Nsout
6320          Rotf=Dout(Oscan,6)
6330          Rotp=1/Rotf
6340          IF Oscan=1 THEN Time=Rotp*(Nav/2-Nstep)
6350          Time=Time+Nstep*Rotp
6360          W=-100*(Pcal1+2*Pcal2*Time)
6370          Area=Dout(Oscan,5)
6380          Vcor=W*Sfw*(Area/Amean-1)
6390          V=Dout(Oscan,4)
6400          V=V+Vcor
6410          Dout(Oscan,4)=V
6420          ! PRINT USING "K,DDD.D,K,DDD.D";"VCOR=",Vcor,"V=";V
6430      NEXT Oscan
6440      !
6450      DATA "Z","T","U","V","AREA","FREQ","EF BL","CC BL","VELERR"
6460      RESTORE 6450
6470      READ Var$(*)
6480      !
6490      IF LEN(Ofile$)=0 THEN 6680
6500      ! compute number of records to create file to hold data.
6510      L=LEN(Drop$)+8+LEN(Downtime$)+8+LEN(Lat$)+8+LEN(Long$)+8
6520      L=L+LEN(Comment$)+8+LEN(Progreu$)+8+LEN(Ifile$)+8+LEN(Runtime$)+8
6530      L=L+8*4+8*11
6540      FOR I=1 TO ROW(Var$)
6550          L=L+LEN(Var$(I))+8
6560      NEXT I
6570      L=L+4*ROW(Dout)*COL(Dout)
6580      Nrec=L/256 DIV 1+1
6590      !
6600      CREATE Ofile$,Nrec      ! standard xtup data format
6610      ASSIGN Ofile$ TO #2
6620      PRINT #2;Drop$,Downtime$,Lat$,Long$,Comment$,Progreu$,Ifile$,Runtime$

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6630 FRINT #2;Nvout,Nsout,Bad,11
6640 PRINT #2;Nav,Nstep,Probe,Mod,Gcc,Gcor,Gef,Efuf,Ccuf,Fh,Fz
6650 PRINT #2;Var$(*),Dout(*)
6660 PRINT #2;END
6670 ASSIGN #2 TO *
6680
6690 DATA -1000, 0,-30,-30, 600, 6,2000,4000, 0 ! plotting scales
6700 DATA 0, 28, 40, 40,1300,9.5,3000,5000,70
6710 DATA -1000, 0,-30,-30, 700, 6,4000,2000, 0
6720 DATA 0, 28, 40, 40,1400,9.5,5000,3000,70
6730 IF Mod<>5 THEN RESTORE 6690
6740 IF Mod=5 THEN RESTORE 6710
6750 READ Plo(*),Phi(*)
6760
6770 ! SETUP PLOTTER FOR 7 WIDE BY 10 HIGH
6780 ON Plotter+1 GOTO 8340,6790,6840,6890
6790 !
6800 PLOTTER IS "GRAPHICS"
6810 LIMIT 0,7*25.4,0,5*25.4
6820 GRAPHICS
6830 GOTO 6930
6840 ! SETUP 9872A
6850 IF File=1 THEN PLOTTER IS "9872A"
6860 LIMIT 600/40,7730/40,280/40,10440/40
6870 FRAME
6880 GOTO 6930
6890 ! SETUP 9872S
6900 IF File=1 THEN PLOTTER IS "9872A"
6910 LIMIT 600/40,7730/40,1060/40,11220/40
6920 FRAME
6930 !
6940 Nhalf=1
6950 IF Plotter=1 THEN Nhalf=2
6960 FOR Half=1 TO Nhalf
6970 IF (Plotter=1) AND (Half=1) THEN 7310
6980 LINE TYPE 1
6990 PEN 1
7000 SETGU
7010 Xgdumax=100*MAX(1,RATIO)
7020 MOVE Xgdumax-25,60
7030 IF Plotter=1 THEN MOVE Xgdumax-45,97
7040 CSIZE 3
7050 IF Plotter=1 THEN CSIZE 3.89
7060 LABEL USING "K";"PROG=";Prognev$
7070 LABEL USING "K";"IFILE=";Ifile$
7080 LABEL USING "K";"OFILE=";Ofile$
7090 !
7100 CSIZE 2
7110 IF Plotter=1 THEN CSIZE 3.89
7120 LABEL USING "K";Runtime$
7130 LABEL USING "K";"NAV=";Nav
7140 LABEL USING "K";"NSTEP=";Nstep
7150 LABEL USING "K";"XTVP S/N=";Probe
7160 LABEL USING "K";"XTVP MOD=";Mod
7170 LABEL USING "K";"GCC=";Gcc
7180 LABEL USING "K";"GCOR=";Gcor
7190 LABEL USING "K";"GEF=";Gef

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7200 LABEL USING "K";"EVCO=";Efuf
7210 LABEL USING "K";"CVCO=";Ccvf
7220 LABEL USING "K";"FH=";Fh
7230 LABEL USING "K";"FZ=";Fz
7240 ! PLOT EACH VARIABLE
7250 Csize=2
7260 IF Plotter=1 THEN Csize=3.89
7270 CSIZE Csize
7280 !
7290 LABEL USING "5A,2(5D.D)";Var$(1),Plo(1),Phi(1)
7300 WHERE Xlab,Ylab
7310 !
7320 FOR Var=2 TO Nvout
7330 Pen=MIN(Var-1,4)
7340 IF Var=9 THEN Pen=1
7350 IF NOT Pub THEN PEN Pen
7360 IF Pub THEN PEN 1
7370 !
7380 IF (Plotter=1) AND (Half=1) THEN 7440
7390 LINE TYPE 1
7400 SETGU
7410 MOVE Xlab,Ylab
7420 LABEL USING "5A,2(5D.D)";Var$(Var),Plo(Var),Phi(Var)
7430 WHERE Xlab,Ylab
7440 !
7450 LINE TYPE 1
7460 IF NOT Pub THEN 7570
7470 PEN 1
7480 IF Var=2 THEN LINE TYPE 4,4
7490 IF Var=3 THEN LINE TYPE 4,1
7500 IF Var=4 THEN LINE TYPE 4,2
7510 IF Var=5 THEN LINE TYPE 7,2
7520 IF Var=6 THEN LINE TYPE 5,2
7530 IF Var=7 THEN LINE TYPE 7,4
7540 IF Var=8 THEN LINE TYPE 8,4
7550 IF Var=9 THEN LINE TYPE 1
7560 GOTO 7610
7570 IF (Plotter=1) AND (Var=4) THEN LINE TYPE 3
7580 IF Var=6 THEN LINE TYPE 5,1
7590 IF Var=7 THEN LINE TYPE 5,2
7600 IF Var=8 THEN LINE TYPE 5,3
7610 !
7620 IF (Plotter=1) AND (Half=1) THEN 7660
7630 MOVE Xlab,Ylab+.8*Csize
7640 DRAW Xlab+11*Csize,Ylab+.8*Csize
7650 Ylab=Ylab-.2*Csize
7660 !
7670 SCALE Plo(Var),Phi(Var),Plo(1),Phi(1)
7680 IF (Plotter=1) AND (Half=1) THEN SCALE Plo(Var),Phi(Var),Plo(1)/2,Phi(1)
7690 IF (Plotter=1) AND (Half=2) THEN SCALE Plo(Var),Phi(Var),Plo(1),Plo(1)/2
7700 ! PLOT THE DATA
7710 P=-2
7720 FOR I=1 TO Nsout
7730 D=Dout(I,Var)
7740 IF D<>Bad THEN 7770

```

```

7750      P=-2
7760      GOTO 7810
7770      !
7780      Z=Dout(I,1)
7790      PLOT D,Z,P
7800      P=-1
7810      NEXT I
7820      SETGU
7830      MOVE 130,0
7840      NEXT Var
7850      IF Plotter<>1 THEN 8070
7860      PEN 1
7870      SCALE 0,1,0,1
7880      IF Half<>1 THEN 7930
7890      MOVE 0,0          ! PARTIAL FRAMES
7900      DRAW 0,1
7910      DRAW 1,1
7920      DRAW 1,0
7930      IF Half<>2 THEN 8030
7940      MOVE 0,1
7950      DRAW 0,0
7960      DRAW 1,0
7970      DRAW 1,1
7980      !
7990      SETGU
8000      MOVE 1,1
8010      PEN 1
8020      LABEL USING "K";Comment$
8030      !
8040      SCALE 0,1,0,1
8050      DUMP GRAPHICS 0,1
8060      GCLEAR
8070      NEXT Half
8080      !
8090      CSIZE Csize
8100      IF Plotter=1 THEN 8150
8110      SETGU
8120      MOVE 1,1
8130      PEN 1
8140      LABEL USING "K";Comment$
8150      !
8160      MOVE 100,0
8170      PEN 0
8180      !
8190      IF Plotter<>1 THEN 8240
8200      EXIT GRAPHICS
8210      PRINTER IS 0
8220      PRINT PAGE;          ! TOP OF FORM ON PRINTER
8230      PRINTER IS Printer
8240      IF Plotter<>3 THEN 8270
8250      OUTPUT 705;"EC"      ! enable cutter on 9872S
8260      OUTPUT 705;"AH"      ! advance half page on 9872S
8270      IF Nfile>1 THEN 8340
8280      ! ONLY EXECUTE THE FOLLOWING CODE IF NFILE=1
8290      FOR V=1 TO Nvout      ! allow different plot scales
8300      DISP Var$(V);Plo(V);Phi(V);
8310      INPUT "ENTER NEW PLOT LIMITS: PLO, PHI",Plo(V),Phi(V)

```

```

8320     NEXT V
8330     GOTO 6770
8340 NEXT File
8350 DISP "FINISHED"
8360 STOP
8370 !
8380 ! *****
8390 DEF FNAtan2(Y,X)          ! FN ATAN2(Y,X) four quadrant arc-tangent
8400 DEG
8410 IF X=0 THEN Vert
8420 Ang=ATN(Y/X)
8430 IF X>0 THEN RETURN Ang
8440 IF Y<0 THEN Q3
8450 Ang=Ang+180
8460 RETURN Ang
8470 Q3: Ang=Ang-180
8480 RETURN Ang
8490 Vert: IF Y<0 THEN Down
8500 Ang=90
8510 RETURN Ang
8520 Down: Ang=-90
8530 RETURN Ang
8540 FNEND
8550 ! *****
8560 SUB Interp(Nin,Nout,Bad,Dzout,SHORT Pin(*),Din(*),Dou(*))
8570 SUBEND
8580 ! *****
8590 SUB Addtime(Mastertime$,Addtime$,Addsecs)
8600 ENTER Mastertime$ USING "#,4(NN,X),NN";Mo,Da,Hr,Mn,Sc
8610 Sc=Sc+Addsecs
8620 Mn=Mn+Sc DIV 60
8630 Sc=Sc MOD 60
8640 Hr=Hr+Mn DIV 60
8650 Mn=Mn MOD 60
8660 Da=Da+Hr DIV 24
8670 Hr=Hr MOD 24
8680 OUTPUT Addtime$ USING 8690;Mo,Da,Hr,Mn,Sc
8690 IMAGE #,4(ZZ,":"),ZZ
8700 SUBEND
8710 ! *****
8720 SUB Polar(X,Y,Amp,Ang)    ! rectangular to polar conversion
8730 DEG
8740 Amp=SQR(X^2+Y^2)
8750 IF X<>0 THEN Ang=ATN(Y/X)
8760 IF (X<0) AND (Y<0) THEN Ang=Ang-180
8770 IF (X<0) AND (Y>=0) THEN Ang=Ang+180
8780 IF (X=0) AND (Y>0) THEN Ang=90
8790 IF (X=0) AND (Y<0) THEN Ang=-90
8800 SUBEND
8810 ! *****
8820 SUB Rect(Amp,Ang,X,Y)    ! polar to rectangular conversion
8830 DEG
8840 X=Amp*COS(Ang)
8850 Y=Amp*SIN(Ang)
8860 SUBEND
8870 ! *****

```

Program SPLOT, Sample Run

SPLOT produces a series of plots of XTVP profiles. Many features are available. One can fit each profile to a polynomial and rotate the profile based on its time and inertial period. One can plot the fit or the profile minus the fit.

The following example shows the program prompts, operator entries and program responses for a typical run of plotting, in Cartesian coordinates, the rotated residues of quadratic fits to each of four profiles.

```

SPLOT0          RUN DATE/TIME=81:04:09:22:55:56
VARIABLE NAMES USED ARE U,V
VELOCITY ERROR LIMIT= 2
DATA FITTED TO A POLYNOMIAL OF DEGREE 2
PLOT THE RESIDUE
PLOTS ARE CARTESIAN
THE RESIDUE PROFILES WERE ROTATED BASED ON REF.TIME OF 0 hr 0 min
FOR A ROTATION PERIOD OF 13.4088046171
ROTATED TO 00:00
A PLOT OF THE RESIDUE WAS MADE USING PEN #1
PLOT IS LABELLED.
INPUT DATA IS PROCESSED.
TIC SIZE = 17.78 mm
PLOT WILL BE 266.7 mm 10.5 in WIDE AND 177.8 mm 7 in HIGH
FILE NO.  FILE NAME      TIME HR MIN      U,V OFFSETS (TICS)
1          539P           00:32          4.0  4.0
2          542P           01:29          4.0  4.0
3          543P           01:56          4.0  4.0
4          544P           02:23          4.0  4.0
TOP 0 m OF PROFILES ZAPPED
PLOT MADE 81:04:09:22:58:59
1 FILE NAME=539P
539          12:02:02:35:50
12:02:02:35:42 XTVP 539 PLAYBACK FAERDES PAT
CREATED BY DXPROW FROM FILE 539R, ON 80:12:04:17:39:41
AVERAGE FIT. NBLOCKS= 30 A= 31.1841502298 -.28223036716 4.97020250700E-04
AVERAGE FIT. NBLOCKS= 30 A= -9.659564307 -.06076936805 2.26920819670E-04
INPUT FILE,VARIABLE,NO. OF GOOD PTS,AVE.,STD. DEV. BASED ON GOOD PTS
539P      U COMP      295      .143      3.921
539P      V COMP      295      .072      3.788
2 FILE NAME=542P
542          12:02:18:42:02
12:02:18:41:56 XTVP 542 PLAYBACK FAERDES PAT
CREATED BY DXPROW FROM FILE 542R, ON 80:12:04:18:40:10
AVERAGE FIT. NBLOCKS= 30 A= 23.6964354786 -.22058932126 3.60916726720E-04
AVERAGE FIT. NBLOCKS= 30 A= -9.2035525367 -.05074011791 2.38360188330E-04
542P      U COMP      279      .162      3.243
542P      V COMP      279      .041      4.564
3 FILE NAME=543P
543          12:02:18:49:36
12:02:18:49:31 XTVP 543 PLAYBACK FAERDES PAT
CREATED BY DXPROW FROM FILE 543R, ON 80:12:04:18:40:10
AVERAGE FIT. NBLOCKS= 30 A= 21.7290090277 -.218441803637 4.43213723550E-04
AVERAGE FIT. NBLOCKS= 30 A= -14.0859444811 .06392939153 -1.48637570070E-04

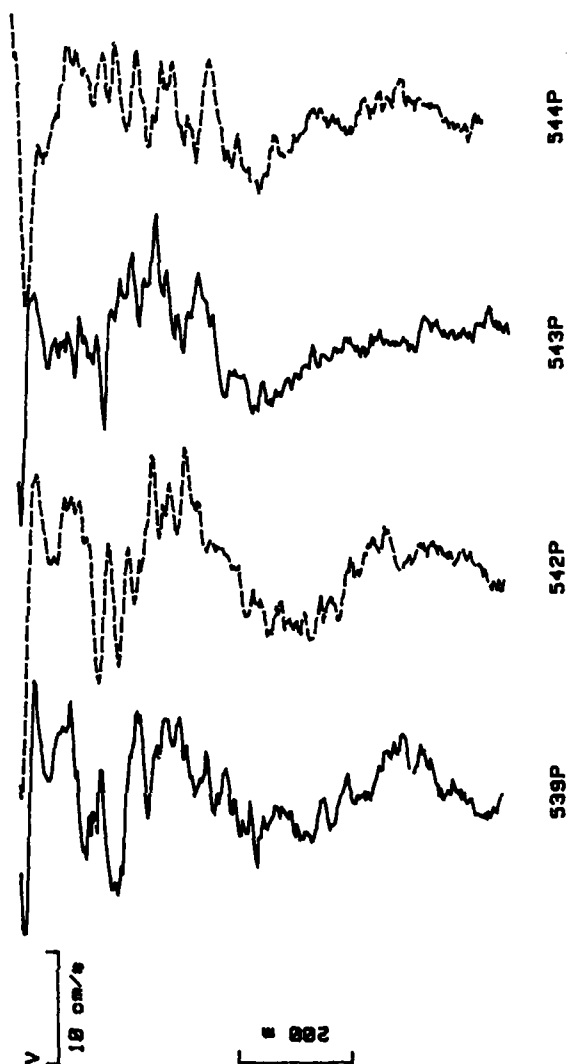
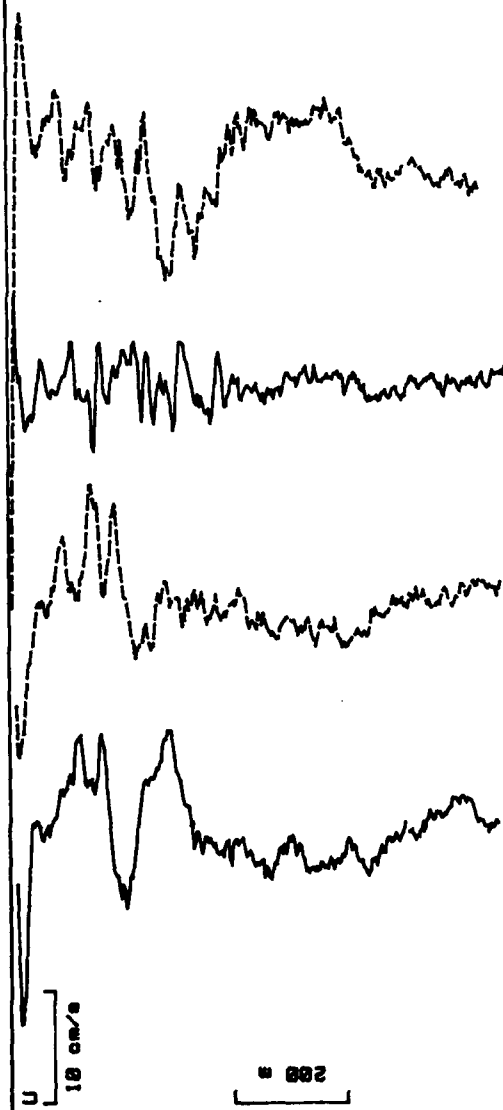
```

543P	U COMP	280	.035	1.613
543P	V COMP	280	.142	3.508

4 FILE NAME=544P

544 12:02:19:00:11
12:02:19:00:06 XTVP 544 PLAYBACK FAEROES PAT
CREATED BY DXPROW FROM FILE 544R, ON 80:12:04:18:40:10
AVERAGE FIT. NBLOCKS= 30 A= 31.332172827 -.34130695143 7.04315634400E-04
AVERAGE FIT. NBLOCKS= 30 A= -20.1443709546 .1250602027 -3.00207033690E-04
544P U COMP 283 -.106 4.867
544P V COMP 283 -.037 3.698

01:04:00:22:50:50
FIT TO DEGREE 2
ROTATED TO 00:00



Program Listing of SPLOT

```

10 Progrev$="SPLOT0"
20 Year=81
30 ! SPLOT : SERIES PLOT BY TOM SANFORD MODIFICATIONS BY JOHN DUNLAP
40 ! THIS PROGRAM ALLOWS FILES TO BE REQUESTED WHICH ARE ON
50 ! SEPARATE DISKS AND PLOTTED WITH OFFSETS FOR Q(U) AND I(V).
60 ! SPLOT0 ALLOWS POLYNOMIAL FIT AND RESIDUES TO BE PLOTTED.
70 ! SPLOT0 ALLOWS THE PROFILES TO BE ROTATED CCW
80 ! SPLOT0 ALLOWS THE RESIDUE PROFILES TO BE PLOTTED IN POLAR FORM
90 ! SPLOT0 ALLOWS FOR VARIOUS VARIABLE POSITIONS IN FILE. SEARCHES NVU$(*).
100 ! SPLOT0 GRAPHICS CRT OR HP-9872A. QUICKER POLYNOMIAL PLOTTING. JHD.
110 ! SPLOT0 NOV 28 79. FIXED ERROR IN VARIABLE NAME SEARCH. JHD.
120 ! SPLOT0 JAN 23 80. SPECIAL NSCAN=500 TO ALLOW FOR ERROR IN FRONTS DXPROG
130 ! SPLOT0 MAY 7 80. FOR NEW XTVP FORMAT.. NOT RIGHT YET. JHD.
140 ! SPLOT0 ... ERIC KUNZE FIXED FROM SPLOT1.
150 ! SPLOT0 ... ALSO ROTATES THE FITS. RECEIVED FROM ERIC KUNZE AS FITPRO.
160 ! SPLOT0 ... MODIFIED TO MAKE VIEW GRAPHS OF WENSTRANDS 8 WITH OUR 191,...
170 ! SPLOT0 ... APR 8 81, FIXED INPUT STATEMENTS TO CHECK PARAMETERS.
180 !
190 !
200 !
210 !
220 !
230 ! SPLOT accepts standard-format processed XTVP files for some specialized
240 ! processing and then plotting to assist scientific analysis. It will plot
250 ! several profiles with the same processing on the same page for easy
260 ! comparison.
270 ! Usually the profiles are fit to a low-degree polynomial
280 ! to remove the low wave-number components. The fits or residuals
290 ! are then plotted instead.
300 ! The residuals can be rotated to a common time according to the
310 ! local inertial period (12 hours divided by the sine of the latitude).
320 ! This allows one to attempt to view a time series or section as if it
330 ! had occurred instantaneously.
340 ! Cartesian or polar plots are available as are various plotters.
350 !
360 ! One specifies the following parameters with defaults in ().
370 ! . variable names (U,V) for processing.
380 ! . velocity error limit (2 cm/s) for use in eliminating noisy data.
390 ! . degree of polynomial fit (0).
400 ! . plot residues or fits (R).
410 ! . cartesian or polar plots (C).
420 ! . whether or not to rotate the plots (N).
430 ! . pen number to use (0).
440 ! . whether to label the plot (Y). Don't label overlays of fits on data.
450 ! . tic size (25.4mm). the plots are 10 cm/s/tic and 200m/tic. The
460 ! default tic size is for 15 by 10 inch paper. To use the 10 by 7
470 ! inch paper use a tic size of 25.4*7/10=17.78. When using the GRAPHICS
480 ! plotter the tic size is adjusted to fit exactly.
490 ! . size of paper in tics. (15,10).
500 ! . size of paper in inches - user can choose three types. Position
510 ! view graphs up from the bottom somewhat.
520 ! . file names until a blank name.
530 ! . if rotating then input the time of the profile.
540 ! . offsets for each component (4,4 tics). This is in addition to the

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```

550 !      normal incrementing of two tics to the right for each profile. Use
560 !      the default value of 4,4 the first time through and refine it later.
570 !      . specify the amount at the top of all profiles to zap in meters.
580 !
590 !      now the program should continue by itself and print each drop header as
600 !      they are read from mass storage. If a file cannot be found then the
610 !      program will prompt for another disc or tape. Plots are drawn as the
620 !      data is processed.
630 !
640 !
650 !
660 !      PRINTER IS 0
670 !      OPTION BASE 1
680 !      OVERLAP
690 !      STANDARD
700 !      DEG
710 !
720 !      DIM File$(16),Offqu(16),Offiv(16)
730 !      DIM Comment$(160),Rmslabel$(80),Now(5)
740 !      DIM Param(100),Nou$(9),A(4),Drot(5),Thr(16),Tmin(16)
750 !      SHORT F(4,500),Fav(4,50)
760 !      SHORT Wav(50),Dav(50,4)
770 !      SHORT D(500,9),W(500),Residue(500)
780 !
790 !      PRINT PAGE
800 !      MAT W=CON
810 !      OUTPUT 9;"R"
820 !      ENTER 9;R$
830 !      R$=VAL$(Year)&":"&R$
840 !      PRINT Progrev$,"RUN DATE/TIME=";R$
850 !
860 !      DIM Var$(3:4)
870 !      IF LEN(Var$(3))=0 THEN Var$(3)="U"
880 !      IF LEN(Var$(4))=0 THEN Var$(4)="Y"
890 !      DISP "VARIABLE NAMES (DEFAULT= ";Var$(3);",";Var$(4);")";
900 !      INPUT Var$(3),Var$(4)
910 !      PRINT "VARIABLE NAMES USED ARE ";Var$(3);",";Var$(4)
920 !
930 !      IF Veler=0 THEN Veler=2
940 !      DISP "VELOCITY ERROR LIMIT (DEFAULT=";Veler;")";
950 !      INPUT Veler
960 !      IF Veler<=0 THEN 940
970 !
980 !      PRINT "VELOCITY ERROR LIMIT=";Veler
990 !      Rmslabel$="VELOCITY ERROR LIMIT="&VAL$(Veler)
1000 !
1010 !      IF LEN(Fit$)=0 THEN Fit$="Y"
1020 !      DISP "IS DATA TO BE FITTED TO POLYNOMIAL (Y OR N; DEFAULT= ";Fit$;")";
1030 !      INPUT Fit$
1040 !      IF (Fit$<>"Y") AND (Fit$<>"N") THEN 1020
1050 !
1060 !      IF Fit$="Y" THEN Fit
1070 !      PRINT "DATA NOT FITTED TO POLYNOMIAL."
1080 !      Rot$="N"          !NO FIT THEN NO ROTATION
1090 !      Polar$="C"        ! NO ROTATION THEN USE CARTISIAN COORD.
1100 !      GOTO 1650

```

```

1110 !
1120 Fit: !
1130 DISP "DEGREE OF POLYNOMIAL FIT (0=CONST,1=LIN,2=QUAD,3=CUBIC; DEFAULT="";D
egree;)" ;
1140 INPUT Degree
1150 IF (Degree<0) OR (Degree>3) THEN 1130
1160 !
1170 PRINT "DATA FITTED TO A POLYNOMIAL OF DEGREE ";Degree
1180 Fitlabel$="FIT TO DEGREE "&VAL$(Degree)
1190 Order=Degree+1
1200 !
1210 IF LEN(Plot$)=0 THEN Plot$="R"
1220 DISP "PLOT FIT OR RESIDUE (F OR R; DEFAULT="";Plot$;" )";
1230 INPUT Plot$
1240 IF (Plot$<>"F") AND (Plot$<>"R") THEN 1220
1250 !
1260 IF Plot$="F" THEN Plttyp$="FIT"
1270 IF Plot$="R" THEN Plttyp$="RESIDUE"
1280 PRINT "PLOT THE ";Plttyp$
1290 !
1300 IF LEN(Polar$)=0 THEN Polar$="C"
1310 DISP "CARTESIAN OR POLAR PLOTS (C OR P; DEFAULT="";Polar$;" )";
1320 INPUT Polar$
1330 IF (Polar$<>"C") AND (Polar$<>"P") THEN 1310
1340 IF Polar$="C" THEN PRINT "PLOTS ARE CARTESIAN"
1350 IF Polar$="P" THEN PRINT "PLOTS ARE POLAR"
1360 !
1370 IF LEN(Rot$)=0 THEN Rot$="N"
1380 DISP "ARE PROFILES TO BE ROTATED (Y OR N; DEFAULT="";Rot$;" )";
1390 INPUT Rot$
1400 IF (Rot$<>"Y") AND (Rot$<>"N") THEN 1380
1410 !
1420 IF Rot$="Y" THEN 1460
1430 !
1440 PRINT "PROFILES ARE NOT ROTATED"
1450 GOTO 1650
1460 !
1470 DISP "ENTER REFERENCE TIME (hr,min; DEFAULT="";T0hr;T0min;" )";
1480 INPUT T0hr,T0min
1490 !
1500 DISP "ROTATION PERIOD (hr.decimal; DEFAULT="";Rotper;" )";
1510 INPUT Rotper
1520 IF Rotper=0 THEN 1500
1530 !
1540 Blankhr$=Blankmin$=""
1550 IF (LEN(VAL$(T0hr))=1) AND (LEN(VAL$(T0min))=1) THEN Blankhr$=Blankmin
$="0"
1560 IF (LEN(VAL$(T0hr))>1) AND (LEN(VAL$(T0min))=1) THEN Blankmin$="0"
1570 IF (LEN(VAL$(T0hr))=1) AND (LEN(VAL$(T0min))>1) THEN Blankhr$="0"
1580 Rotlabel$="ROTATED TO "&Blankhr$&VAL$(T0hr)&":"&Blankmin$&VAL$(T0min)
1590 !
1600 PRINT "THE RESIDUE PROFILES WERE ROTATED BASED ON REF.TIME OF ";T0hr;"
hr ";T0min;"min "
1610 PRINT " FOR A ROTATION PERIOD OF ";Rotper
1620 PRINT Rotlabel$
1630 !

```

```

1640     Pen=VAL(Pen$)
1650     DISP "PEN NUMBER TO BE USED (1,2,3 OR 4; 0 FOR ALL; DEFAULT="";Pen;" )"
;
1660     INPUT Pen
1670     IF (Pen<0) OR (Pen>4) THEN 1650
1680     Pen$=VAL$(Pen)
1690     !
1700     PRINT "A PLOT OF THE ";Plttyp$;" WAS MADE USING PEN #";Pen$
1710 !
1720     IF LEN(Label$)=0 THEN Label$="Y"
1730     DISP "LABEL PLOT (Y OR N; DEFAULT="";Label$;" )";
1740     INPUT Label$
1750     IF (Label$<>"Y") AND (Label$<>"N") THEN 1730
1760 !
1770     IF Label$="N" THEN PRINT "PLOT IS NOT LABELLED."
1780     IF Label$="Y" THEN PRINT "PLOT IS LABELLED."
1790 !
1800     Ans$="P"
1810 !     DISP "RAW OR PROCESSED DATA INPUT (R OR P; DEFAULT="";Ans$;"");
1820 !     INPUT Ans$
1830     IF (Ans$<>"R") AND (Ans$<>"P") THEN 1810
1840 !
1850     IF Ans$="R" THEN Datatyp$="RAW"
1860     IF Ans$="P" THEN Datatyp$="PROCESSED"
1870     PRINT "INPUT DATA IS ";Datatyp$;". "
1880 !
1890 Plotter_setup: !                               PLOTTER_SETUP
1900 !
1910     IF Plotter=0 THEN Plotter=2
1920     DISP "GRAPHICS (1), 9872A (2) OR 9872S (3);DEFAULT="";Plotter;"");
1930     INPUT Plotter
1940     IF (Plotter<0) OR (Plotter>3) THEN 1920
1950 !
1960     IF Plotter=0 THEN 2470
1970     !
1980     IF Plotter=1 THEN 2010
1990     DISP "PAPER OR ACETATE FILM (0 OR 1; DEFAULT="";Film;"");
2000     INPUT Film
2010     !
2020     IF Tic=0 THEN Tic=25.4
2030     DISP "TIC SIZE (mm; DEFAULT="";Tic;"");
2040     INPUT Tic
2050     PRINT "TIC SIZE ="";Tic;" mm"
2060     !
2070     IF Xtics=0 THEN Xtics=15
2080     IF Ytics=0 THEN Ytics=10
2090     DISP "NUMBER OF XTICS, YTICS (DEFAULT="";Xtics;Ytics;"");
2100     INPUT Xtics,Ytics
2110     IF (Xtics<0) OR (Xtics>100) THEN 2090
2120     IF (Ytics<0) OR (Ytics>100) THEN 2090
2130     !
2140     Xmm=Tic*Xtics
2150     Ymm=Tic*Ytics
2160     PRINT "PLOT WILL BE ";Xmm;"mm";Xmm/25.4;"in WIDE AND ";Ymm;" mm ";Ymm/25.
4;"in HIGH"

```

```

2170  Change$="N"
2180  INPUT "DO YOU WANT TO CHANGE THE SPECS? (Y/N)",Change$
2190  IF Change$="Y" THEN 2020
2200  !
2210  ON Plotter GOTO Graphics,Hp9872a,Hp9872s
2220  !
2230  Hp9872s: !
2240  Hp9872a: !
2250  !
2260  IF Paper=0 THEN Paper=3
2270  IF NOT Film THEN DISP "PAPER TYPE (1=7W,10H. 2=15W,10H. 3=10W,7H,HOLES U
P; DEFAULT="";Paper;")";
2280  IF NOT Film THEN INPUT Paper
2290  !
2300  IF Paper=1 THEN OUTPUT 705 USING "K";"IP600,260,7730,10420"
2310  IF Paper=2 THEN OUTPUT 705 USING "K";"IP600,260,15876,10401"
2320  IF Paper=3 THEN OUTPUT 705 USING "K";"IP77,269,10252,7377"
2330  !
2340  PLOTTER IS "9872A"
2350  !
2360  IF Film THEN OUTPUT 705;"VS10;" !LIMIT PEN VELOCITY TO 10 CM/S WHEN FIL
M IS USED
2370  IF Pen$<>"0" THEN PEN VAL(Pen$)
2380  IF Label$="Y" THEN FRAME
2390  PEN 0
2400  GOTO 2530
2410  !
2420  Graphics: PLOTTER IS "GRAPHICS"
2430  GRAPHICS
2440  Tic=MIN(184.47/Xtics,149.82/Ytics)
2450  PRINT "GRAPHICS TIC SIZE CHANGED TO";Tic;"mm TO FIT SCREEN"
2460  LIMIT 0,Xtics*Tic,0,Ytics*Tic
2470  MSCALE Tic,Tic
2480  LINE TYPE 3
2490  GRID Tic,Tic
2500  LINE TYPE 1
2510  FRAME
2520  EXIT GRAPHICS
2530  IF Ans$="R" THEN Raw
2540  IF Ans$="P" THEN Proc
2550  !
2560  Raw: !
2570  Zsc=Tic/50 ! 50 SEC PER TIC
2580  Dsc=Tic/(1.25*1016) ! ABOUT 10 CM/S PER TIC
2590  Plotsx$=VAL$(Tic*20/(2.5*1016)/Dsc)&" cm/s"
2600  Plotsy$=VAL$(Tic/Zsc)&" sec"
2610  GOTO 2700
2620  !
2630  Proc: !
2640  Zsc=Tic/200 ! 200 M PER TIC
2650  Dsc=Tic/10 ! 10 CM/S PER TIC
2660  Plotsx$=VAL$(Tic/Dsc)&" cm/s"
2670  Plotsy$=VAL$(Tic/Zsc)&" m"
2680  !
2690  PRINT "FILE NO. FILE NAME TIME HR MIN SETUP FILE NAMES AND PARAMETERS
2700  FOR File=1 TO 16 U,V OFFSETS (TICS)"

```

```

2710      !
2720      DISP "FILE NAME FOR FILE NUMBER=";File;
2730      EDIT File$(File)
2740      !
2750      IF LEN(File$(File))=0 THEN 3060      ! BLANK INDICATES END OF INPUT LIST
2760      !
2770      File$=File$(File)
2780      IF POS(File$,".") THEN 2840
2790      ASSIGN #1 TO File$(File),Ret
2800      IF Ret=0 THEN 2860
2810          BEEP
2820          DISP "THIS FILE NOT ON THIS DISC.  ";
2830          GOTO 2720
2840      DISP "IMPROPER FILE NAME.  ";
2850      GOTO 2720
2860      !
2870      IF Ret$="N" THEN 2950
2880      !
2890      DISP "ENTER DROP TIME (hr,min; DEFAULT=";Thr(File);Tmin(File);")";
2900      INPUT Thr(File),Tmin(File)
2910      IF (Thr(File)<-1000) OR (Thr(File)>=1000) THEN 2890
2920      IF (Tmin(File)<0) OR (Tmin(File)>=60) THEN 2890
2930      !
2940      IMAGE #,4D,6X,15A,3X,2Z,"",2Z
2950      PRINT USING 2940;File;File$(File);Thr(File);Tmin(File)
2960      !
2970      IF Offqu(File)=0 THEN Offqu(File)=4
2980      IF Offiv(File)=0 THEN Offiv(File)=4
2990      DISP "U, V OFFSET (tics; DEFAULT=";Offqu(File);",";Offiv(File);")";
3000      INPUT Offqu(File),Offiv(File)
3010      PRINT USING 3020;Offqu(File);Offiv(File)
3020      IMAGE 8X,3D.D,      3D.D
3030      !
3040      NEXT File      !*****
3050      !
3060      Nfile=File-1
3070      !
3080      DISP "ZAP TOP OF PROFILES (meters; DEFAULT=";Zzap;")";
3090      INPUT Zzap
3100      Zzap=-ABS(Zzap)
3110      IF Zzap>1000 THEN 3080
3120      PRINT "TOP";ABS(Zzap);"m OF PROFILES ZAPPED"
3130      !
3140      OUTPUT 9;"R"
3150      ENTER 9;Now$
3160      Now$=VAL$(Year)&":"&Now$
3170      PRINT USING "K";"PLOT MADE ";Now$
3180      !
3190          IF Plotter=1 THEN GRAPHICS
3200      !
3210      ! ***** START OF FILE LOOP TO PROCESS AND PLOT *****
3220      !
3230      FOR File=1 TO Nfile
3240          Penuse=VAL(Pen$)
3250          IF Pen$="0" THEN Penuse=(File-1) MOD 4+1
3260          PRINT File;"FILE NAME=";File$(File)

```

```

3270  ASSIGN #1 TO File$(File),Ret
3280  IF Ret=0 THEN 3320
3290    BEEP
3300    EDIT "THIS FILE NOT FOUND ON THIS DISC",File$(File)
3310    GOTO 3270
3320    READ #1,1
3330  READ #1;Drop$,Downtime$,Lat$,Long$
3340  PRINT Drop$,Downtime$,Lat$,Long$
3350  !
3360  READ #1;Comment$
3370  PRINT Comment$
3380  !
3390  READ #1;Oldprog$,Oldfile$,Created$
3400  PRINT USING 3410;Oldprog$,Oldfile$,Created$
3410  IMAGE "CREATED BY ",K," FROM FILE ",K," ON ",K
3420  !
3430  READ #1;Nvar,Nscan,Bad,Nparam
3440  REDIM Param(Nparam),Nvu$(Nvar),D(Nscan,Nvar)
3450  READ #1;Param(*),Nvu$(*),D(*)
3460  !
3470  FOR I=1 TO Nscan
3480    IF D(I,9)<Veler THEN 3510
3490    D(I,3)=Bad
3500    D(I,4)=Bad
3510  NEXT I
3520  !
3530  FOR V=3 TO 4          ! SEARCH FOR VARIABLES BY NAME
3540    FOR L=1 TO Nvar
3550      IF Nvu$(L)[1;LEN(Var$(V))]=Var$(V) THEN 3650
3560    NEXT L
3570      BEEP
3580      EXIT GRAPHICS
3590      PRINTER IS 16
3600      PRINT Nvu$(*)
3610      PRINTER IS 0
3620      EDIT "CAN'T FIND VARIABLE BELOW.  CHOOSE NAME FROM ABOVE LIST",Var$(
V)
3630      GRAPHICS
3640      GOTO 3540
3650      Var(V)=L
3660  NEXT V
3670  DIM Var(9)
3680  !
3690  IF Ans$="R" THEN Dz=-.5
3700  !
3710  FOR V=3 TO 4
3720    FOR I=1 TO Nscan
3730      IF D(I,1)<Zzap THEN 3750
3740      D(I,V)=Bad
3750    NEXT I
3760  NEXT V
3770  LINE TYPE 1
3780  CSIZE 2
3790  IF Plotter=1 THEN CSIZE 2.8
3800  LONG 9
3810  LDIR 0

```

```

3820  MSCALE 0,0
3830  IF Label$="N" THEN 3970
3840  IF File>1 THEN 3970
3850  PEN 1
3860  SETGU
3870  Xgdumax=100*MAX(1,RATIO)
3880  Ygdumax=100*MAX(1,1/RATIO)
3890  MOVE .99*Xgdumax,.99*Ygdumax
3900  IMAGE 3(ZZ,X),2(ZZ,":"),ZZ
3910  LABEL USING "K";Now$
3920  LABEL USING "K";Fitlabel$
3930  LABEL USING "K";Rmslabel$
3940  IF Rot$="N" THEN 3960
3950  LABEL USING "K";Rotlabel$
3960  SETUU
3970  Xoff=2*Tic*(1+File)-1.5*Tic  !MOVE EACH PLOT OVER 1 TIC STARTING AT 2
3980  MSCALE Xoff,0  ! PLOT IN mm
3990  MOVE 0,2
4000  LORG 4
4010  PEN Penuse
4020  IF Label$="Y" THEN LABEL USING "K";File$(File)
4030  PEN 0
4040  !
4050  IF Fit$="N" THEN 4700  !SKIP OVER FITTING PORTION
4060  !
4070  FOR I=1 TO Nscan  ! SET UP FITTING FUNCTIONS
4080  F(1,I)=1
4090  F(2,I)=I
4100  F(3,I)=I^2
4110  F(4,I)=I^3
4120  NEXT I
4130  !
4140  Nblocks=30
4150  REDIM Fav(4,Nblocks),Wav(Nblocks),Dav(Nblocks,4)
4160  Blocksize=Nscan DIV Nblocks
4170  FOR J=1 TO Nblocks
4180  FOR V=1 TO Order
4190  Fav=0
4200  FOR L=1 TO Blocksize
4210  I=(J-1)*Blocksize+L
4220  Fav=Fav+F(I*(V-1))
4230  NEXT L
4240  Fav(V,J)=Fav/Blocksize
4250  NEXT V
4260  NEXT J
4270  !
4280  FOR J=1 TO Nblocks
4290  Wav=0
4300  FOR K=1 TO Blocksize
4310  I=(J-1)*Blocksize+K
4320  Wav=Wav+W(I)
4330  NEXT K
4340  Wav(J)=Wav/Blocksize
4350  NEXT J
4360  !
4370  MAT Dav=(Dav)

```

```

4380     FOR V=3 TO 4
4390     Var=Var(V)
4400     FOR J=1 TO Nblocks
4410     Dav=0
4420     Nav=0
4430     FOR K=1 TO Blocksize
4440     I=(J-1)*Blocksize+K
4450     D=D(I,Var)
4460     IF D=Bad THEN 4490
4470     Dav=Dav+D
4480     Nav=Nav+1
4490     NEXT K
4500     IF Nav THEN Dav(J,V)=Dav/Nav
4510     NEXT J
4520     NEXT V
4530 !                                     OBTAIN FIT FROM AVERAGED DATA, FIT, WEIGHTING
4540     FOR V=3 TO 4
4550     Var=Var(V)
4560     CALL Lsqw2(A(*),V,Nblocks,Order,Bad,Ngood,1,Dav(*),Wav(*),Fav(*))
4570     PRINT "AVERAGE FIT. NBLOCKS=";Nblocks;
4580     PRINT USING "K,X";"A=";A(*)
4590 !
4600     FOR I=1 TO Nscan
4610     IF D(I,Var)=Bad THEN 4680
4620     Fit=0
4630     FOR J=1 TO Order           ! FORM FIT
4640     Fit=Fit+F(J,I)*A(J)
4650     NEXT J
4660     IF Plot$="F" THEN D(I,Var)=Fit
4670     IF Plot$="R" THEN D(I,Var)=D(I,Var)-Fit
4680     NEXT I
4690     NEXT V
4700 !                                     END OF Var LOOP #1
4710 !                                     START OF Var LOOP #2: DATA IS PLOTTED
4720     PEN Penuse
4730     FOR V=3 TO 4
4740     Var=Var(V)
4750     V3=Var(3)
4760     V4=Var(4)
4770     Yoff=Tic*5*(5-V)           ! PUT U ABOVE V, EACH 5 TICS HIGH
4780     Offset=Offqu(File)*Tic     ! OFFSET 0(U)
4790     IF V=4 THEN Offset=Offiv(File)*Tic ! OFFSET I(V)
4800     LOG 3
4810     MSCALE 0,Yoff
4820     LINE TYPE 1
4830     IF File>1 THEN 5080
4840     IF Label$="N" THEN 5080
4850     MOVE 2,-2
4860     LDIR 0
4870     IF Polar$="C" THEN 4910
4880     Nvu$(V3)="SPEED"
4890     Nvu$(V4)="PHASE"
4900     IF V=4 THEN Plotsx$="200 deg"
4910     LABEL USING "K";Nvu$(Var)
4920     MOVE Tic/10,-3*Tic/10
4930     DRAW Tic/10,-4*Tic/10

```

```

4940      DRAW 11*Tic/10,-4*Tic/10
4950      DRAW 11*Tic/10,-3*Tic/10
4960      MOVE 6*Tic/10,-5*Tic/10
4970      LORG 6
4980      LDIR 0
4990      LABEL USING "K";Plotsx$
5000      MOVE 2*Tic/10,-2*Tic
5010      DRAW Tic/10,-2*Tic
5020      DRAW Tic/10,-3*Tic
5030      DRAW 2*Tic/10,-3*Tic
5040      MOVE 3*Tic/10,-2.5*Tic
5050      LORG 6
5060      LDIR 90
5070      LABEL USING "K";Plotsy$
5080      IF Pen$="0" THEN 5110
5090          IF File MOD 2=1 THEN LINE TYPE 1
5100          IF File MOD 2=0 THEN LINE TYPE 5,1
5110      P=-2
5120      MSCALE Xoff,Yoff
5130      !
5140      ! PLOT THE DATA
5150          Slide=4*Tic
5160          Ngood=9r=Ssr=9rw=Ssrw=0
5170          IF Rot$="N" THEN 5230
5180          !
5190          Angle=(Thr(File)-T0hr+(Tmin(File)-T0min)/60)*360/Rotper
5200          IF Ans$="R" THEN Angle=-1*Angle      ! FOR RAW DATA QUAD-PHASE CORRESPON
DS TO EAST, HENCE THE NEED TO CHANGE ANGLE
5210          Cos=COS(Angle)
5220          Sin=SIN(Angle)
5230          FOR Scan=1 TO Nscan
5240              D=D(Scan,Var)
5250              D3=D(Scan,V3)
5260              D4=D(Scan,V4)
5270              IF (D3<>Bad) AND (D4<>Bad) THEN 5310
5280              D3=D4=Bad
5290              P=-2
5300              GOTO 5610
5310              Y=D(Scan,1)*Zsc
5320              IF (Rot$="N") OR (V=4) THEN 5380
5330              Drot(3)=D3*COS-D4*SIN
5340              Drot(4)=D3*SIN+D4*COS
5350              D=Drot(Var)
5360              D3=Drot(3)
5370              D4=Drot(4)
5380              IF Polar$="C" THEN 5510
5390              IF Ans$="R" THEN D3=-D3
5400              D=SQR(D3^2+D4^2)
5410              IF V=3 THEN 5510
5420              D=ATN(D3/D4)
5430              IF (D3<0) AND (D4>0) THEN D=D+180
5440              IF (D3<0) AND (D4<0) THEN D=D-180
5450              X=D*Tic/200      ! 200 DEG PER TIC FOR PHASE
5460              IF ABS(D-Dlast)<200 THEN 5520
5470              Dlast=D
5480              P=-2

```

```

5490      GOTO 5610
5500      !
5510      X=D*Dsc-Slide+Offset      ! OFFSET TO LEFT BY 4 TICS PLUS DESIRED
OFFSET
5520      Dlast=D
5530      Ngood=Ngood+1
5540      Sr=Sr+D
5550      Ssr=Ssr+D^2
5560      Xw=D*W(Scan)
5570      Srw=Srw+Xw
5580      Ssrw=Ssrw+Xw^2
5590      PLOT X,Y,P
5600      P=-1
5610      !
5620      D(Scan,3)=D3
5630      D(Scan,4)=D4
5640      NEXT Scan
5650      !
5660      Avg=Sr/Ngood
5670      Sig=SQR(Ssr/Ngood-Avg^2)
5680      Avgw=Srw/Ngood
5690      Sigw=SQR(Ssrw/Ngood-Avgw^2)
5700      IF Ans$="P" THEN 5740
5710      Comptyp$="QUAD-PHASE"
5720      IF V=4 THEN Comptyp$="IN-PHASE"
5730      GOTO 5800
5740      Comptyp$="U COMP"
5750      IF V=4 THEN Comptyp$="V COMP"
5760      IF File>1 THEN 5800      !PRINT HEADING ONCE
5770      IF V>3 THEN 5800
5780      PRINT "INPUT FILE,VARIABLE,NO. OF GOOD PTS,AVE.,STD. DEV. BASED ON GOOD
PTS"
5790      IMAGE 4X,6A,4X,10A,4X,DDD,DDDD.DDD,4X,DDD.DDD
5800      PRINT USING 5790;File$(File),Comptyp$,Ngood,Avgw,Sigw
5810      NEXT V
5820      PEN 0
5830      NEXT File
5840      PEN 0
5850      BEEP
5860      ! IF Plotter=1 THEN PRINT PAGE
5870      ! IF Plotter=1 THEN DUMP GRAPHICS
5880      ! IF Plotter=1 THEN PRINT PAGE
5890      IF Plotter=1 THEN EXIT GRAPHICS
5900      DISP Progrev$;
5910      INPUT " FINISHED.  0 TO STOP,  1 TO CHANGE OFFSETS AND  REPLO7",Control
5920      ON Control+1 GOTO 5930,Plotter_setup
5930      STOP
5940      !
5950      END
5960      ! *****
5970      SUB Lsqw2(A(*),Var,Nscan,Order,Bad,Ngood,I1,SHORT D(*),W(*),F(*))
5980      OPTION BASE 1
5990      DIM C(Order,Order),Ci(Order,Order),B(Order)
6000      Ngood=0
6010      FOR I=1 TO Nscan
6020      D=D(I+I1-1,Var)

```

```

6030 IF D=Bad THEN 6120
6040 Ngood=Ngood+1
6050 FOR J=1 TO Order
6060 Fw=F(J,I)*W(I)
6070 B(J)=B(J)+Fw*D
6080 FOR K=1 TO J
6090 C(J,K)=C(J,K)+Fw*F(K,I)
6100 NEXT K
6110 NEXT J
6120 NEXT I
6130 FOR J=1 TO Order
6140 FOR K=1 TO J
6150 C(K,J)=C(J,K)
6160 NEXT K
6170 NEXT J
6180 MAT Ci=INV(C)
6190 MAT A=Ci*B
6200 SUBEND
6210 END

```

Program CROSS, Sample Run

CROSS is a program that computes cross correlation, structure functions and coherences between pairs of profiles. The operator can select the number of profiles, number of variables in each profile, plotter to use, depth interval and depth interpolation interval.

The operator sets up the program in advance for many operations; the computer can then be left unattended. This program can be very time consuming, depending on the options selected.

The following is an example of computing structure functions of seven profiles for both east and north components.

```
PRINTER ? (0=THERMAL, 16=CRT)
0
CROSSE SEPT 24 80   RUN DATE AND TIME = 81:04:08:23:41:27
NUMBER OF VARIABLES ?
2
NUMBER OF VARIABLES = 2
NUMBER OF FILES ?
7
NUMBER OF FILES = 7
PLOTTER ? (0=NONE, 1=GRAPHICS, 2=9872A)
0
PLOTTER$=NONE
PROCESSING OPTION? (1=CROSS CORRELATION, 2=STRUCTURE FUNCTION, 3=COHERANCE)
2
PROCESSING OPTION=STRUCTURE
FIRST, LAST DEPTH TO PROCESS ?
200, 800
FIRST, LAST DEPTH TO PROCESS = -200 -800
NUMBER OF POINTS PER PIECE ?
50
NUMBER OF POINTS PER PIECE = 50
NUMBER OF PIECES?
2
NUMBER OF PIECES= 2
TOTAL NUMBER OF POINTS USED= 100
DEPTH INCREMENT=-6.06060606061
DEPTH PER PIECE=-296.96969697
MAX DEPTH LAG ?
20
MAX DEPTH LAG = 20
MAXIMUM RMSERR ALLOWED FOR XTVP DATA?
3
MAXIMUM RMSERR ALLOWED FOR XTVP DATA= 3
TYPE FILE NAME FOR FILE No. 1

82P
WHICH 2 VARIABLE No.s TO PROCESS?
```

3,4
VAR No. FOR RMSERR IN XTVP FILES? (0 FOR NONE)
9
FILE No.= 1 FILENAME=82P VARIABLES=U, V, VELERR.
TYPE FILE NAME FOR FILE No. 2

83P
WHICH 2 VARIABLE No.s TO PROCESS?

3,4
VAR No. FOR RMSERR IN XTVP FILES? (0 FOR NONE)
9
FILE No.= 2 FILENAME=83P VARIABLES=U, V, VELERR.
TYPE FILE NAME FOR FILE No. 3

84P
WHICH 2 VARIABLE No.s TO PROCESS?

U,V
WHICH 2 VARIABLE No.s TO PROCESS?

U,V
WHICH 2 VARIABLE No.s TO PROCESS?

3,4
VAR No. FOR RMSERR IN XTVP FILES? (0 FOR NONE)
9
FILE No.= 3 FILENAME=84P VARIABLES=U, V, VELERR.
TYPE FILE NAME FOR FILE No. 4

85P
WHICH 2 VARIABLE No.s TO PROCESS?

3,4
VAR No. FOR RMSERR IN XTVP FILES? (0 FOR NONE)
9
FILE No.= 4 FILENAME=85P VARIABLES=U, V, VELERR.
TYPE FILE NAME FOR FILE No. 5

86P
WHICH 2 VARIABLE No.s TO PROCESS?

3,4
VAR No. FOR RMSERR IN XTVP FILES? (0 FOR NONE)
9
FILE No.= 5 FILENAME=86P VARIABLES=U, V, VELERR.
TYPE FILE NAME FOR FILE No. 6

87P
WHICH 2 VARIABLE No.s TO PROCESS?

3,4
VAR No. FOR RMSERR IN XTVP FILES? (0 FOR NONE)
9
FILE No.= 6 FILENAME=87P VARIABLES=U, V, VELERR.
TYPE FILE NAME FOR FILE No. 7

88P

WHICH 2 VARIABLE No.s TO PROCESS?

3,4

VAR No. FOR RMSERR IN XTVP FILES? (0 FOR NONE)

9

FILE No.= 7 FILENAME=88P VARIABLES=U, V, VELERR.
NUMBER OF SETS OF COMBINATIONS ?

3

NUMBER OF SETS OF COMBINATIONS = 3
No. FILES IN SET No. 1 ?

3

WHICH 3 FILE No.s FOR SET No. 1 ?

1,2,3

SET= 1 HAS FILE No.s: 1 , 2 , 3 .
No. FILES IN SET No. 2 ?

4

WHICH 4 FILE No.s FOR SET No. 2 ?

3,4,5,6

SET= 2 HAS FILE No.s: 3 , 4 , 5 , 6 .
No. FILES IN SET No. 3 ?

3

WHICH 3 FILE No.s FOR SET No. 3 ?

1,2,7

SET= 3 HAS FILE No.s: 1 , 2 , 7 .

SET	FILENO	FILENAME	VARIABLE								
1	1	82P	U								
	2	83P	U								
DEPTH RANGE		AV1	AV2	ZLAG	AVDIF	RMSDIF	RMSMIN	OK1	OK2	RMS1	RMS2
(meters)				(m)				fraction			

INTERPOLATING

PROCESSING STRUCTURE

-200	-497	-9.23	-9.77	-18	-.14	1.65	1.65	1.00	1.00	1.7	1.4
------	------	-------	-------	-----	------	------	------	------	------	-----	-----

INTERPOLATING

PROCESSING STRUCTURE

-497	-794	-6.48	-5.22	6	.12	2.12	2.12	1.00	1.00	3.5	4.4
------	------	-------	-------	---	-----	------	------	------	------	-----	-----

SET	FILENO	FILENAME	VARIABLE								
1	1	82P	V								
	2	83P	V								
DEPTH RANGE		AV1	AV2	ZLAG	AVDIF	RMSDIF	RMSMIN	OK1	OK2	RMS1	RMS2
(meters)				(m)				fraction			

INTERPOLATING

PROCESSING STRUCTURE

-200	-497	-2.92	4.78	-18	.40	2.51	2.51	1.00	1.00	3.5	1.7
INTERPOLATING											

PROCESSING STRUCTURE

-497	-794	-7.31	.18	-6	.12	2.93	2.93	1.00	1.00	2.6	2.1
------	------	-------	-----	----	-----	------	------	------	------	-----	-----

SET FILENO	FILENAME	VARIABLE									
1	1	82P	U								
	3	84P	U								
DEPTH RANGE	AV1	AV2	ZLAG	AVDIF	RMSDIF	RMSMIN	OK1	OK2	RMS1	RMS2	
(meters)			(m)								
INTERPOLATING											

PROCESSING STRUCTURE

-200	-497	-9.23	-12.66	18	.34	2.72	2.72	1.00	1.00	1.7	2.1
INTERPOLATING											

PROCESSING STRUCTURE

-497	-794	-6.48	-5.49	6	.13	2.73	2.73	1.00	1.00	3.5	4.2
------	------	-------	-------	---	-----	------	------	------	------	-----	-----

SET FILENO	FILENAME	VARIABLE									
1	1	82P	V								
	3	84P	V								
DEPTH RANGE	AV1	AV2	ZLAG	AVDIF	RMSDIF	RMSMIN	OK1	OK2	RMS1	RMS2	
(meters)			(m)								
INTERPOLATING											

PROCESSING STRUCTURE

-200	-497	-2.92	6.72	-18	.51	2.77	2.77	1.00	1.00	3.5	1.8
INTERPOLATING											

PROCESSING STRUCTURE

-497	-794	-7.31	2.38	-18	.38	3.43	3.43	1.00	1.00	2.6	2.9
------	------	-------	------	-----	-----	------	------	------	------	-----	-----

SET FILENO	FILENAME	VARIABLE									
1	2	83P	U								
	3	84P	U								
DEPTH RANGE	AV1	AV2	ZLAG	AVDIF	RMSDIF	RMSMIN	OK1	OK2	RMS1	RMS2	
(meters)			(m)								
INTERPOLATING											

PROCESSING STRUCTURE

-200	-497	-9.77	-12.66	-18	.00	3.02	3.02	1.00	1.00	1.4	2.1
INTERPOLATING											

PROCESSING STRUCTURE

-497	-794	-5.22	-5.49	0	-.00	2.24	2.24	1.00	1.00	4.4	4.2
------	------	-------	-------	---	------	------	------	------	------	-----	-----

SET	FILENO	FILENAME	VARIABLE									
1	2	83P	V									
3	84P	V										
DEPTH RANGE	AV1	AV2	ZLAG	AVDIF	RMSDIF	RMSMIN	OK1	OK2	RMS1	RMS2		
(meters)			(m)					fraction				
INTERPOLATING												
PROCESSING STRUCTURE												
-200 -497	4.78	6.72	18	-.10	1.84	1.84	1.00	1.00	1.7	1.8		
INTERPOLATING												
-497 -794	.18	2.38	-12	.21	3.13	3.13	1.00	1.00	2.1	2.9		
SET	FILENO	FILENAME	VARIABLE									
2	3	84P	U									
4	85P	U										
DEPTH RANGE	AV1	AV2	ZLAG	AVDIF	RMSDIF	RMSMIN	OK1	OK2	RMS1	RMS2		
(meters)			(m)					fraction				
-200 -497	-12.66	-15.18	0	-.00	2.74	2.74	1.00	1.00	2.1	2.0		
-497 -794	-5.49	-8.61	-18	-.65	2.24	2.24	1.00	1.00	4.2	3.4		
SET	FILENO	FILENAME	VARIABLE									
2	3	84P	V									
4	85P	V										
DEPTH RANGE	AV1	AV2	ZLAG	AVDIF	RMSDIF	RMSMIN	OK1	OK2	RMS1	RMS2		
(meters)			(m)					fraction				
-200 -497	6.72	2.84	6	-.13	3.42	3.42	1.00	1.00	1.8	3.7		
-497 -794	2.38	-3.64	-18	-.04	3.37	3.37	1.00	1.00	2.9	2.0		
SET	FILENO	FILENAME	VARIABLE									
2	3	84P	U									
5	86P	U										
DEPTH RANGE	AV1	AV2	ZLAG	AVDIF	RMSDIF	RMSMIN	OK1	OK2	RMS1	RMS2		
(meters)			(m)					fraction				
-200 -497	-12.66	-13.81	18	-.15	2.89	2.89	1.00	1.00	2.1	1.9		
-497 -794	-5.49	-5.63	18	.64	2.53	2.53	1.00	1.00	4.2	4.5		
SET	FILENO	FILENAME	VARIABLE									
2	3	84P	V									
5	86P	V										
DEPTH RANGE	AV1	AV2	ZLAG	AVDIF	RMSDIF	RMSMIN	OK1	OK2	RMS1	RMS2		
(meters)			(m)					fraction				
-200 -497	6.72	-6.32	18	-.78	4.20	4.20	1.00	1.00	1.8	5.2		
-497 -794	2.38	-10.18	-12	.02	3.40	3.40	1.00	1.00	2.9	2.1		
SET	FILENO	FILENAME	VARIABLE									
2	3	84P	U									
6	87P	U										
DEPTH RANGE	AV1	AV2	ZLAG	AVDIF	RMSDIF	RMSMIN	OK1	OK2	RMS1	RMS2		
(meters)			(m)					fraction				
-200 -497	-12.66	-15.90	18	.15	3.79	3.79	1.00	1.00	2.1	2.4		
-497 -794	-5.49	-5.27	-18	-.74	2.77	2.77	1.00	1.00	4.2	3.1		
SET	FILENO	FILENAME	VARIABLE									
2	3	84P	V									
6	87P	V										
DEPTH RANGE	AV1	AV2	ZLAG	AVDIF	RMSDIF	RMSMIN	OK1	OK2	RMS1	RMS2		

(meters)				(m)								
-200 -497	6.72	-2.26	18	.12	2.71	2.71	1.00	1.00	1.8	2.6		
-497 -794	2.38	.94	6	-.12	3.51	3.51	1.00	1.00	2.9	2.2		

SET FILENO	FILENAME		VARIABLE									
2	4	85P	U									
	5	86P	U									
DEPTH RANGE	AV1	AV2	ZLAG	AVDIF	RMSDIF	RMSMIN	OK1	OK2	RMS1	RMS2		
(meters)			(m)									
-200 -497	-15.18	-13.81	-12	-.19	1.92	1.92	1.00	1.00	2.0	1.9		
-497 -794	-8.61	-5.63	0	.00	2.25	2.25	1.00	1.00	3.4	4.5		

SET FILENO	FILENAME		VARIABLE									
2	4	85P	V									
	5	86P	V									
DEPTH RANGE	AV1	AV2	ZLAG	AVDIF	RMSDIF	RMSMIN	OK1	OK2	RMS1	RMS2		
(meters)			(m)									
-200 -497	2.84	-6.32	-18	.76	2.51	2.51	1.00	1.00	3.7	5.2		
-497 -794	-3.64	-10.18	-6	-.06	2.35	2.35	1.00	1.00	2.0	2.1		

SET FILENO	FILENAME		VARIABLE									
2	4	85P	U									
	6	87P	U									
DEPTH RANGE	AV1	AV2	ZLAG	AVDIF	RMSDIF	RMSMIN	OK1	OK2	RMS1	RMS2		
(meters)			(m)									
-200 -497	-15.18	-15.90	6	.20	2.70	2.70	1.00	1.00	2.0	2.4		
-497 -794	-8.61	-5.27	0	.00	2.41	2.41	1.00	1.00	3.4	3.1		

SET FILENO	FILENAME		VARIABLE									
2	4	85P	V									
	6	87P	V									
DEPTH RANGE	AV1	AV2	ZLAG	AVDIF	RMSDIF	RMSMIN	OK1	OK2	RMS1	RMS2		
(meters)			(m)									
-200 -497	2.84	-.26	12	.05	2.62	2.62	1.00	1.00	3.7	2.6		
-497 -794	-3.64	.94	-18	.16	2.70	2.70	1.00	1.00	2.9	2.2		

SET FILENO	FILENAME		VARIABLE									
2	5	86P	U									
	6	87P	U									
DEPTH RANGE	AV1	AV2	ZLAG	AVDIF	RMSDIF	RMSMIN	OK1	OK2	RMS1	RMS2		
(meters)			(m)									
-200 -497	-13.81	-15.90	18	.32	2.28	2.28	1.00	1.00	1.9	2.4		
-497 -794	-5.63	-5.27	0	.00	3.14	3.14	1.00	1.00	4.5	3.1		

SET FILENO	FILENAME		VARIABLE									
2	5	86P	V									
	6	87P	V									
DEPTH RANGE	AV1	AV2	ZLAG	AVDIF	RMSDIF	RMSMIN	OK1	OK2	RMS1	RMS2		
(meters)			(m)									
-200 -497	-6.32	-.26	18	-.19	3.84	3.84	1.00	1.00	5.2	2.6		
-497 -794	-10.18	.94	18	-.21	2.78	2.78	1.00	1.00	2.1	2.2		

SET FILENO	FILENAME		VARIABLE
3	1	82P	U
	2	83P	U

DEPTH RANGE (meters)	AV1	AV2	ZLAG (m)	AVDIF	RMSDIF	RMSMIN	OK1 fraction	OK2	RMS1	RMS2
-200 -497	-9.23	-9.77	-18	-.14	1.65	1.65	1.00	1.00	1.7	1.4
-497 -794	-6.48	-5.22	6	.12	2.12	2.12	1.00	1.00	3.5	4.4

SET FILENO FILENAME
3 1 82P
2 83P

VARIABLE
V
V

DEPTH RANGE (meters)	AV1	AV2	ZLAG (m)	AVDIF	RMSDIF	RMSMIN	OK1 fraction	OK2	RMS1	RMS2
-200 -497	-2.92	4.78	-18	.40	2.51	2.51	1.00	1.00	3.5	1.7
-497 -794	-7.31	.18	-6	.12	2.93	2.93	1.00	1.00	2.6	2.1

SET FILENO FILENAME
3 1 82P
7 88P

VARIABLE
U
U

DEPTH RANGE (meters)	AV1	AV2	ZLAG (m)	AVDIF	RMSDIF	RMSMIN	OK1 fraction	OK2	RMS1	RMS2
-200 -497	-9.23	-15.91	18	.63	2.01	2.01	1.00	1.00	1.7	2.9
-497 -794	-6.48	-4.92	18	-.04	3.58	3.58	1.00	1.00	3.5	2.0

SET FILENO FILENAME
3 1 82P
7 88P

VARIABLE
V
V

DEPTH RANGE (meters)	AV1	AV2	ZLAG (m)	AVDIF	RMSDIF	RMSMIN	OK1 fraction	OK2	RMS1	RMS2
-200 -497	-2.92	-16.71	18	.15	5.99	5.99	1.00	1.00	3.5	3.6
-497 -794	-7.31	-9.48	18	.32	3.30	3.30	1.00	1.00	2.6	3.8

SET FILENO FILENAME
3 2 83P
7 88P

VARIABLE
U
U

DEPTH RANGE (meters)	AV1	AV2	ZLAG (m)	AVDIF	RMSDIF	RMSMIN	OK1 fraction	OK2	RMS1	RMS2
-200 -497	-9.77	-15.91	18	.45	2.49	2.49	1.00	1.00	1.4	2.9
-497 -794	-5.22	-4.92	18	.18	4.24	4.24	1.00	1.00	4.4	2.0

SET FILENO FILENAME
3 2 83P
7 88P

VARIABLE
V
V

DEPTH RANGE (meters)	AV1	AV2	ZLAG (m)	AVDIF	RMSDIF	RMSMIN	OK1 fraction	OK2	RMS1	RMS2
-200 -497	4.78	-16.71	18	.41	4.43	4.43	1.00	1.00	1.7	3.6
-497 -794	.18	-9.48	-12	.00	3.44	3.44	1.00	1.00	2.1	3.8

Listing of Program CROSS

```

10  ! CROSS CORRELATION, STRUCTURE FUNCTION OR COHERANCE BETWEEN TWO PROFILES.
20  ! SPECIALLY MODIFIED TO ZAP U,V OF XTVP PROFILES WHEN RMSERR>MAXERR.
30  ! J. DUNLAP
40  ! SEPT 17 1980 . CROSSD HAS COHERANCE ADDED.
50  ! SEPT 24 1980.  CROSSE HAS COHERANCE WORKING AFTER A FASHION.
60
70  Progrev$="CROSSE SEPT 24 80"
80  Year=80
90
100  NORMAL
110  STANDARD
120  OVERLAP
130  OPTION BASE 1
140  INPUT "PRINTER ? (0=THERMAL, 16=CRT)",Printer
150  PRINTER IS Printer
160
170  OUTPUT 9;"R"
180  ENTER 9;Runtime$
190  Runtime$=VAL$(Year)&":"&Runtime$
200
210  DIM Comment$[160],Param(100),Nvu$(9)
220
230  DIM Comment1$[160],Param1(100),Nvu1$(9)
240  SHORT D1(500,9)
250
260  DIM Param2(100),Nvu2$(9),Comment2$[160]
270  SHORT D2(500,9)
280
290  DIM Y1(2000),Y2(2000),R12(100)
300
310  PRINT Progrev$,"RUN DATE AND TIME = ";Runtime$
320
330  INPUT "NUMBER OF VARIABLES ?",Npair
340  PRINT "NUMBER OF VARIABLES =";Npair
350
360  INPUT "NUMBER OF FILES ?",Nfile
370  PRINT "NUMBER OF FILES =";Nfile
380
390  DIM Lup(50,3),Lupp(3),File$(50),Luprms(50)
400  REDIM Lup(Nfile,Npair),Lupp(Npair),File$(Nfile),Luprms(Nfile)
410
420  INPUT "PLOTTER ? (0=NONE, 1=GRAPHICS, 2=9872A)",Plotter
430  IF Plotter=0 THEN Plotter$="NONE"
440  IF Plotter=1 THEN Plotter$="GRAPHICS"
450  IF Plotter=2 THEN Plotter$="9872A"
460  PRINT "PLOTTER$=";Plotter$
470
480  INPUT "PROCESSING OPTION? (1=CROSS CORRELATION, 2=STRUCTURE FUNCTION, 3=COHERANCE)",Process
490  IF (Process<1) OR (Process>3) THEN 480
500  IF Process=1 THEN Process$="CROSSCOR"
510  IF Process=2 THEN Process$="STRUCTURE"
520  IF Process=3 THEN Process$="COHERANCE"
530  PRINT "PROCESSING OPTION=";Process$
540

```

```

550 INPUT "FIRST, LAST DEPTH TO PROCESS ?", Z1, Z2
560 Z1 = -ABS(Z1)
570 Z2 = -ABS(Z2)
580 PRINT "FIRST, LAST DEPTH TO PROCESS ="; Z1; Z2
590 !
600 INPUT "NUMBER OF POINTS PER PIECE ?", Npp
601 Npp = PROUND(Npp, 0)
610 PRINT "NUMBER OF POINTS PER PIECE ="; Npp
620 !
630 INPUT "NUMBER OF PIECES?", Npie
631 Npie = PROUND(Npie, 0)
640 PRINT "NUMBER OF PIECES="; Npie
650 !
660 Nuse = Npie * Npp
670 Dz = -ABS((Z2 - Z1) / (Nuse - 1))
680 Zpp = -ABS((Npp - 1) * Dz)
690 !
700 PRINT "TOTAL NUMBER OF POINTS USED="; Nuse
710 PRINT "DEPTH INCREMENT="; Dz
720 PRINT "DEPTH PER PIECE="; Zpp
730 !
740 IF (Process$ <> "CROSSCOR") AND (Process$ <> "STRUCTURE") THEN 780
750 INPUT "MAX DEPTH LAG ?", Zlagmax
760 PRINT "MAX DEPTH LAG ="; Zlagmax
770 Nlagmax = ABS((Zlagmax + .1 * Dz) DIV Dz)
780 !
790 IF Process$ <> "COHERANCE" THEN 850
800 INPUT "NO. FREQ. BANDS TO AVERAGE?", Nband
810 PRINT "NO. FREQ. BANDS TO AVERAGE="; Nband
820 !
830 Nfft = Npp
840 PRINT "NUMBER OF POINTS IN FFT=NUMBER OF POINTS PER PIECE="; Nfft
850 !
860 REDIM R12(-Nlagmax:Nlagmax), Y1(Npp), Y2(Npp)
870 !
880 INPUT "MAXIMUM RMSERR ALLOWED FOR XTVP DATA?", Rmsmaxallowed
890 PRINT "MAXIMUM RMSERR ALLOWED FOR XTVP DATA="; Rmsmaxallowed
900 !
910 ! ***** GET FILE NAMES AND VARIABLES FOR EACH FILE
920 !
930 FOR File=1 TO Nfile
940 !
950 DISP "TYPE FILE NAME FOR FILE No."; File;
960 EDIT " ", File$(File)
970 !
980 ASSIGN File$(File) TO #1, Ret
990 IF Ret=0 THEN 1040
1000 BEEP
1010 DISP "CANNOT FIND THE FOLLOWING FILE. PLEASE EDIT OR TRY ANOTHER TAP
E/DISC.";
1020 GOTO 960
1030 !
1040 READ #1, 1
1050 READ #1; Drop$, Datetime$, Lat$, Long$, Comment$, Fromnog$, Fromfile$, Created$
1060 READ #1; Nvar, Nscan, Bad, Nparam
1070 REDIM Nvu$(Nvar), Param(Nparam)

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```

1080 READ #1;Param(*),Nvu$(*)
1090 !
1100 PRINTER IS 16
1110 PRINT "FILE=";File$(File)
1120 PRINT "VARIABLE No.", "VARIABLE NAME"
1130 FOR L=1 TO Nvar
1140 PRINT L,Nvu$(L)
1150 NEXT L
1160 PRINTER IS Printer
1170 !
1180 FOR Pair=1 TO Npair
1190 Lupp(Pair)=Lup(File,Pair)
1200 NEXT Pair
1210 !
1220 DISP "WHICH";Npair;"VARIABLE No.s TO PROCESS?";
1230 INPUT "",Lupp(*)
1240 !
1250 FOR Pair=1 TO Npair
1260 IF (Lupp(Pair)<1) OR (Lupp(Pair)>Nvar) THEN 1220
1270 Lup(File,Pair)=Lupp(Pair)
1280 NEXT Pair
1290 !
1300 INPUT "VAR No. FOR RMSERR IN XTVP FILES? (0 FOR NONE)",Luprms(File)
1310 IF (Luprms(File)<0) OR (Luprms(File)>Nvar) THEN 1300
1320 !
1330 PRINT "FILE No.=";File;" FILENAME=";File$(File);" VARIABLES=";
1340 FOR Pair=1 TO Npair
1350 PRINT Nvu$(Lup(File,Pair));", ";
1360 NEXT Pair
1370 !
1380 IF Luprms(File) THEN PRINT Nvu$(Luprms(File));"."
1390 IF NOT Luprms(File) THEN PRINT "."
1400 NEXT File
1410 !
1420 ! DETERMINE THE SET BOUNDRIES
1430 ! IN ONE SET ALL THE COMBINATIONS WILL BE USED
1440 !
1450 INPUT "NUMBER OF SETS OF COMBINATIONS ?",Nset
1460 PRINT "NUMBER OF SETS OF COMBINATIONS =" ;Nset
1470 !
1480 DIM Fileno(50,20),Nfile(20)
1490 REDIM Fileno(Nfile,Nset),Nfile(Nset)
1500 !
1510 FOR Set=1 TO Nset
1520 DISP "No. FILES IN SET No.";Set;"?";
1530 INPUT "",Nfile(Set)
1540 IF (Nfile(Set)<2) OR (Nfile(Set)>Nfile) THEN 1520
1550 !
1560 DIM Filen(20)
1570 REDIM Filen(Nfile(Set))
1580 !
1590 FOR F=1 TO Nfile(Set)
1600 Filen(F)=Fileno(F,Set)
1610 NEXT F
1620 !
1630 DISP "WHICH";Nfile(Set);"FILE No.s FOR SET No.";Set;"?";

```

```

1640 INPUT "",Filen(*)
1650 ! CHECK FILE No.s
1660 FOR F=1 TO Nfile(Set)
1670 IF (Filen(F)<1) OR (Filen(F)>Nfile) THEN 1630
1680 Fileno(F,Set)=Filen(F)
1690 NEXT F
1700 !
1710 PRINT "SET=";Set;"HAS FILE No.s:";
1720 FOR F=1 TO Nfile(Set)-1
1730 PRINT Fileno(F,Set);", ";
1740 NEXT F
1750 PRINT Fileno(Nfile(Set),Set);"."
1760 !
1770 NEXT Set
1780 !
1790 ! ***** READ DATA FROM ALL PAIRS OF FILES FROM EACH SET
1800 !
1810 FOR Set=1 TO Nset
1820 FOR File1=1 TO Nfile(Set)-1
1830 ! INPUT FILE 1
1840 File1no=Fileno(File1,Set)
1850 File1$=File$(File1no)
1860 ASSIGN File1$ TO #1,Ret
1870 IF Ret=0 THEN 1930
1880 DISP "CANNOT FIND FILE = ";File$(File1);". TRY ANOTHER DISC/TAPE THEN
1890 PUSH CONT
1900 BEEP
1910 PAUSE
1920 DISP ""
1930 GOTO 1860
1940 READ #1,1
1950 READ #1;Drop1$,Datetime1$,Lat$,Long1$
1960 READ #1;Comment1$,Fromprog1$,Fromfile1$,Created1$
1970 READ #1;Nvar1,Nscan1,Bad1,Nparam1
1980 REDIM Nvu1$(Nvar1),D1(Nscan1,Nvar1),Param1(Nparam1)
1990 READ #1;Param1(*),Nvu1$(*),D1(*)
2000 !
2010 ! SET DATA BAD WHICH HAVE RMSERR LARGER THAN RMSMAX
2020 ! JUST FOR VARIABLES USED
2030 !
2040 Luprms=Luprms(File1)
2050 IF Luprms=0 THEN 2130
2060 FOR I=1 TO Nscan1
2070 Rms=D1(I,Luprms)
2080 IF Rms<Rmsmaxallowed THEN 2120
2090 FOR Var=1 TO Npair
2100 Lup=Lup(File1,Var)
2110 D1(I,Lup)=Bad1
2120 NEXT Var
2130 !
2140 FOR File2=File1+1 TO Nfile(Set)
2150 ! INPUT FILE 2
2160 File2no=Fileno(File2,Set)
2170 File2$=File$(File2no)
2180 ASSIGN File2$ TO #2,Ret

```

```

2190      IF Ret=0 THEN 2250
2200      BEEP
2210      DISP "CANNOT FIND FILE = ";File$(File2);". TRY ANOTHER TAPE/DISC T
HEN PUSH CONT"
2220      PAUSE
2230      DISP ""
2240      GOTO 2180
2250      READ #2,1
2260      READ #2;Drop2$,Datetime2$,Lat2$,Long2$
2270      READ #2;Comment2$,Fromprog2$,Fromfile2$,Created2$
2280      READ #2;Nvar2,Nscan2,Bad2,Nparam2
2290      REDIM Nvu2$(Nvar2),D2(Nscan2,Nvar2),Param2(Nparam2)
2300      READ #2;Param2(*),Nvu2$(*),D2(*)
2310      !
2320      ! SET DATA BAD WHICH HAVE RMSERR LARGER THAN RMSMAX
2330      ! JUST FOR VARIABLES USED
2340      !
2350      Luprms=Luprms(File2)
2360      IF Luprms=0 THEN 2450
2370      FOR I=1 TO Nscan2
2380      Rms=D2(I,Luprms)
2390      IF Rms<Rmsmaxallowed THEN 2440
2400      FOR Var=1 TO Npair
2410      Lup=Lup(File2,Var)
2420      D2(I,Lup)=Bad2
2430      NEXT Var
2440      NEXT I
2450      !
2460      IF Plotter$="NONE" THEN 2500
2470      PLOTTER IS Plotter$
2480      Xgdu=100*MAX(1,RATIO)
2490      Ygdu=100*MAX(1,1/RATIO)
2500      !
2510      FOR Pair=1 TO Npair
2520      Lup1=Lup(File1,Pair)
2530      Lup2=Lup(File2,Pair)
2540      !
2550      PRINT USING 2560;Set,File1no,File1$,Nvu1$(Lup1),File2no,File2$,Nvu2
$(Lup2)
2560      IMAGE /,"SET FILENO FILENAME VARIABLE",/,3D,X,3D,4X,18A,18
A,/,4X,3D,4X,18A,18A
2570      !
2580      IF Process$<>"CROSSCOR" THEN 2620
2590      PRINT "DEPTH RANGE      AV1      AV2  R12MAX ZLAG      AVDIF  RMSDIF  0
K1 OK2 RMS1 RMS2"
2600      PRINT " (meters)                                (m)                                f
raction
2610      GOTO 2660
2620      !
2630      IF Process$<>"STRUCTURE" THEN 2660
2640      PRINT "DEPTH RANGE      AV1      AV2 ZLAG      AVDIF  RMSDIF  RMSMIN  0
K1 OK2 RMS1 RMS2"
2650      PRINT " (meters)                                (m)                                f
raction
2660      !
2670      IF (Process$<>"STRUCTURE") AND (Process$<>"CROSSCOR") THEN 3770

```

```

2680      !
2690      FOR Pie=1 TO Npie
2700          Zp1=Z1+(Pie-1)*Zpp
2710          Zp2=Zp1+Zpp
2720          !
2730          !                               INTERPOLATE D1(*),D2(*) INTO Y1(*),Y2(*)
2740          DISP "INTERPOLATING"
2750          CALL Interp(D1(*),Nscan1,1,Lup1,Zp1,Dz,Npp,Bad1,Y1(*))
2760          CALL Interp(D2(*),Nscan2,1,Lup2,Zp1,Dz,Npp,Bad2,Y2(*))
2770          !
2780          !                               COMPUTE AVERAGES AND RMS PER PIECE
2790          S1=S2=0
2800          Ss1=Ss2=0
2810          Nok1=Nok2=0
2820          FOR I=1 TO Npp
2830              Y1=Y1(I)
2840              Y2=Y2(I)
2850              IF Y1=Bad1 THEN 2880
2860              Nok1=Nok1+1
2870              S1=S1+Y1
2880              Ss1=Ss1+Y1^2
2890              IF Y2=Bad2 THEN 2920
2900              Nok2=Nok2+1
2910              S2=S2+Y2
2920              Ss2=Ss2+Y2^2
2930          NEXT I
2940          Av1=Av2=0
2950          Std1=Std2=0
2960          IF Nok1 THEN Av1=S1/Nok1
2970          IF Nok1 THEN Std1=SQR(Ss1/Nok1-Av1^2)
2980          IF Nok2 THEN Av2=S2/Nok2
2990          IF Nok2 THEN Std2=SQR(Ss2/Nok2-Av2^2)
3000          !
3010          !                               FORCE Y1(*), Y2(*) TO ZERO MEAN PER PIECE
3020          FOR I=1 TO Npp
3030              IF Y1(I)<>Bad1 THEN Y1(I)=Y1(I)-Av1
3040              IF Y2(I)<>Bad2 THEN Y2(I)=Y2(I)-Av2
3050          NEXT I
3060          !
3070          DISP "PROCESSING ";Process$
3080          IF Process$="CROSSCOR" THEN CALL Crosscor(Y1(*),Y2(*),Npp,-Nlagmax,Nlagmax,R12(*),S11,S22,Bad1,Bad2,Ok1,Ok2)
3090          IF Process$="STRUCTURE" THEN CALL Structure(Y1(*),Y2(*),Npp,-Nlagmax,Nlagmax,R12(*),Bad1,Bad2,Ok1,Ok2)
3100          DISP ""
3110          !
3120          IF Process$<>"CROSSCOR" THEN 3210
3130          !
3140          !                               CROSS CORRELATION: FIND LAG WITH MAX CORRELATION
3150          R12max=-1
3160          FOR Lag=-Nlagmax TO Nlagmax
3170              IF R12max>R12(Lag) THEN 3170
3180              R12max=R12(Lag)
3190              Mlag=Lag
3200          NEXT Lag
3210          Zlag=0
3220          IF R12max<>0 THEN Zlag=Mlag*Dz
3230          !
3240          IF Process$<>"STRUCTURE" THEN 3320
3250          !
3260          !                               STRUCTURE FUNCTION: FIND LAG WITH RMS MINIMUM

```

```

3230      Rmsmin=R12(0)
3240      Mlag=0
3250      FOR Lag=-Nlagmax TO Nlagmax
3260          IF Rmsmin<R12(Lag) THEN 3290
3270          Rmsmin=R12(Lag)
3280          Mlag=Lag
3290      NEXT Lag
3300      Zlag=0
3310      IF Rmsmin>0 THEN Zlag=Mlag*Dz
3320      !
3330      Nd=Sd=Sdd=0          ! GET AVG AND RMS OF DIFFERENCE AT MLAG
3340      FOR I=MAX(1,1-Mlag) TO MIN(Npp,Npp-Mlag)
3350          Y1=Y1(I)
3360          Y2=Y2(I+Mlag)
3370          IF (Y1=Bad1) OR (Y2=Bad2) THEN 3420
3380          Dif=Y1-Y2
3390          Nd=Nd+1
3400          Sd=Sd+Dif
3410          Sdd=Sdd+Dif^2
3420      NEXT I
3430      !
3440      Avdif=Rmsdif=0
3450      IF Nd=0 THEN 3480
3460      Avdif=Sd/Nd
3470      Rmsdif=SQR(Sdd/Nd-Avdif^2)
3480      !
3490      IF Process$<>"CROSSCOR" THEN 3530
3500      !                                PRINT FOR CROSS CORRELATION
3510      PRINT USING 3520;Zp1,Zp2,Av1,Av2,R12max;Zlag;Avdif;Rmsdif,Ok1,Ok2
,Std1,Std2
3520      IMAGE 2(5D),2(5D.DD),4D.3D,5D,2(5D.DD),2(2D.2D),2(5D.D)
3530      !
3540      IF Process$<>"STRUCTURE" THEN 3580
3550      !                                PRINT FOR STRUCTURE FUNCTION
3560      PRINT USING 3570;Zp1,Zp2,Av1,Av2,Zlag,Avdif,Rmsdif,Rmsmin,Ok1,Ok2
,Std1,Std2
3570      IMAGE 2(5D),2(5D.2D),5D,3(5D.2D),2(2D.2D),2(5D.D)
3580      !
3590      IF Plotter$="NONE" THEN 3760
3600      IF Plotter$="GRAPHICS" THEN GRAPHICS
3610      !
3620      Xbox=Xgdu/Npair
3630      Ybox=Ygdu/Npie
3640      !
3650      LOCATE Xbox*(Pair-1),Xbox*Pair,Ybox*(Npie-Pie),Ybox*(Npie-Pie+1)
3660      FRAME
3670      IF Process$="CROSSCOR" THEN SCALE -Nlagmax,Nlagmax,-1,1
3680      IF Process$="STRUCTURE" THEN SCALE -Nlagmax,Nlagmax,0,5
3690      !
3700      P=-2
3710      FOR Lag=-Nlagmax TO Nlagmax
3720          PLOT Lag,R12(Lag),P
3730          P=-1
3740      NEXT Lag
3750      IF Plotter$="9872A" THEN PENUP
3760      NEXT Pie
3770      !

```

```

3780     IF Process$<>"COHERANCE" THEN 3880
3790     Nppp=Npp*Npie
3800     REDIM Y1(Nppp),Y2(Nppp)
3810     DISP "INTERPOLATING"
3820     Lup1=Lup(File1,Pair)
3830     Lup2=Lup(File2,Pair)
3840     CALL Interp(D1(*),Nscan1,1,Lup1,Z1,Dz,Nppp,Bad1,Y1(*))
3850     CALL Interp(D2(*),Nscan2,1,Lup2,Z1,Dz,Nppp,Bad2,Y2(*))
3860     !
3870     CALL Coher(Y1(*),Y2(*),Nppp,Nfft,Nband,Idif,Dz,Nvu1$(Lup1),Nvu2$(Lup
p2))
3880     !
3890     NEXT Pair
3900     !
3910     IF Plotter$<>"GRAPHICS" THEN 4050
3920     !
3930     PRINT PAGE
3940     PRINT "PROGRAM=";Progrev$,"RUN DATE&TIME";Runtime$
3950     PRINT "PROCESS=";Process$
3960     IF Printer<>0 THEN 4000
3970     DUMP GRAPHICS
3980     PRINT PAGE
3990     !
4000     EXIT GRAPHICS
4010     GCLEAR
4020     !
4030     IF Plotter$<>"9872A" THEN 4060
4040     !
4050     PEN 0
4060     !
4070     NEXT File2
4080     NEXT File1
4090     NEXT Set
4100     !
4110     DISP "FINISHED"
4120     STOP
4130     !
4140     ! *****
4150     SUB Junk
4160     SUBEND
4170     ! *****
4180     SUB Crosscor(X(*),Y(*),N,L1,L2,Rxy(*),Sxx,Syy,Badx,Bady,Okx,Oky)
4190     Sxx=Syy=Nokx=Noky=0
4200     FOR I=1 TO N
4210     X=X(I)
4220     IF X=Badx THEN 4250
4230     Nokx=Nokx+1
4240     Sxx=Sxx+X^2
4250     Y=Y(I)
4260     IF Y=Bady THEN 4290
4270     Noky=Noky+1
4280     Syy=Syy+Y^2
4290     NEXT I
4300     Okx=Nokx/N
4310     Oky=Noky/N
4320     !
4330     MAT Rxy=ZER

```

```

4340 IF (Sxx=0) OR (Syy=0) THEN SUBEXIT
4350 !
4360 FOR L=L1 TO L2
4370   Sxy=0
4380   FOR I=MAX(1,1-L) TO MIN(N,N-L)
4390     J=I+L
4400     X=X(I)
4410     IF X=Badx THEN 4460
4420     Y=Y(J)
4430     IF Y=Bady THEN 4460
4440     Sxy=Sxy+X*Y
4450     Nokxy=Nokxy+1
4460   NEXT I
4470   Rxy(L)=Sxy/SQR(Sxx*Syy)
4480 NEXT L
4490 SUBEND
4500 ! *****
4510 SUB Junk
4520 SUBEND
4530 ! *****
4540 SUB Structure(X(*),Y(*),N,L1,L2,Rmslag(*),Badx,Bady,Okx,Oky)
4550   Nokx=Noky=0
4560   FOR I=1 TO N
4570     IF X(I)<>Badx THEN Nokx=Nokx+1
4580     IF Y(I)<>Bady THEN Noky=Noky+1
4590   NEXT I
4600   Okx=Nokx/N
4610   Oky=Noky/N
4620   !
4630   FOR Lag=L1 TO L2
4640     Nd=Sd=Sdd=0
4650     FOR I=MAX(1,1-Lag) TO MIN(N,N-Lag)
4660       X=X(I)
4670       Y=Y(I+Lag)
4680       IF (X=Badx) OR (Y=Bady) THEN 4730
4690       Nd=Nd+1
4700       Dif=X-Y
4710       Sd=Sd+Dif
4720       Sdd=Sdd+Dif^2
4730     NEXT I
4740     Av=Rms=0
4750     IF Nd=0 THEN 4780
4760     Av=Sd/Nd
4770     Rms=SQR(Sdd/Nd-Av^2)
4780     Rmslag(Lag)=Rms
4790   NEXT Lag
4800 SUBEND
4810 END
4820 ! *****
4830 SUB Interp(SHORT Din(*),REAL Nin,Zvar,Dvar,Z1,Dz,Nout,Bad,Dout(*))
4840 ! JUL 8,80 JHD. MODIFIED TO WORK WITH 2 DIM ARRAY INPUT, 1 DIM OUT
4850   OPTION BASE 1
4860   Dp=ABS(Dz)
4870   P1=ABS(Z1)
4880   MAT Dout=(Bad)
4890   J=2
4900   FOR Iout=1 TO Nout

```

```

4910      Pout=P1+(Iout-1)*Dp
4920      FOR J=J TO Nin          ! FIND PIN(J) JUST GREATER THAN POUT
4930          Pj=ABS(Din(J,Zvar))
4940          Dj=Din(J,Dvar)
4950          IF (Pj>Pout) AND (Dj<>Bad) THEN 4980
4960      NEXT J
4970      SUBEXIT
4980          IF Pj<>Pout THEN 5010 ! SPECIAL SPEED-UP IF PJ=POUT
4990          Dout(Iout)=Dj
5000          GOTO 5070
5010      I=J-1                  ! INTERPOLATE LINEARLY IF PI<POUT
5020      Pi=ABS(Din(I,Zvar))
5030      Di=Din(I,Dvar)
5040      IF Pi>Pout THEN 5070
5050      IF Di=Bad THEN 5070
5060      Dout(Iout)=(Dj-Di)/(Pj-Pi)*(Pout-Pi)+Di
5070  NEXT Iout
5080  SUBEND
5090  !
5100  ! *****
5110  !
5120 SUB Coher(X(*),Y(*),Nin,Nfft,Nband,Idif,Delz,Labx$,Laby$)
5130 OPTION BASE 1
5140 SHORT Xx(Nfft),Yy(Nfft)
5150 Deg=180/PI
5160 Rad=1/Deg
5170 Delz=ABS(Delz)
5180 Npie=Nin DIV Nfft
5190 Nh=Nfft/2
5200 Dof=Nband*Npie
5210 IF Dof>1 THEN 5240
5220 DISP "DEGREES OF FREEDOM TOO SMALL"
5230 GOTO 5260
5240 T95=1.96+2.38/Dof+2.64/Dof^2+2.56/Dof^3
5250 C95=SQR(1-(1-.95)^(1/(Dof-1)))
5260 !
5270 PRINT "COHERANCE BETWEEN ";Labx$;" AND ";Laby$
5280 PRINT "NIN=";Nin,"NFFT=";Nfft,"NBAND=";Nband
5290 PRINT "NPIE=";Npie,"C95=";C95,"DOF=";Dof
5300 PRINT " 1 EST 2 WNO WLEN AXX AYY CXY QXY RXY
      PXY DPH"
5310 IMAGE 2(3D),5D.D,4D.2D,4(X,MD.2DE),2D.2D,2(5D)
5320 IF Idif=0 THEN S7
5330 FOR I=1 TO Nin-1
5340     X(I)=X(I+1)-X(I)
5350     Y(I)=Y(I+1)-Y(I)
5360 NEXT I
5370 X(Nin)=X(Nin-1)
5380 Y(Nin)=Y(Nin-1)
5390 S7:          ! FFT
5400 FOR L=1 TO Npie
5410     L0=(L-1)*Nfft
5420     FOR I=1 TO Nfft
5430         Xx(I)=X(L0+I)
5440         Yy(I)=Y(L0+I)
5450     NEXT I
5460 !

```

```

5470      CALL Fork(Xx(*),Yy(*),Nfft,1)
5480 !
5490      Sc=SQR(2)/Nfft
5500      FOR I=1 TO Nfft
5510          X(L0+I)=Xx(I)*Sc
5520          Y(L0+I)=Yy(I)*Sc
5530      NEXT I
5540  NEXT L
5550 !
5560  FOR V=0 TO 4
5570      Kk=0
5580      FOR K=1 TO Nh-1 STEP Nband
5590          Rxx=Ryy=Cxy=Qxy=Nav=0
5600          FOR L=1 TO Npie
5610              L1=(L-1)*Nfft+1
5620              Ii=L1+K
5630              Jj=L1+Nfft-K
5640              FOR M=0 TO MIN(Nband,Nh-K)-1
5650                  I=Ii+M
5660                  J=Jj-M
5670                  Xc=X(I)+X(J)
5680                  Xs=Y(I)-Y(J)
5690                  Yc=Y(I)+Y(J)
5700                  Ys=X(J)-X(I)
5710                  Cxy=Cxy+.5*(Xc*Yc+Xs*Ys)
5720                  Qxy=Qxy+.5*(Yc*Xs-Xc*Ys)
5730                  Rxx=Rxx+.5*(Xc^2+Xs^2)
5740                  Ryy=Ryy+.5*(Yc^2+Ys^2)
5750                  Nav=Nav+1
5760              NEXT M
5770          NEXT L
5780 !
5790          IF Idif<>1 THEN S22
5800          Recolor=4*SIN(PI*(K+.5*(Nband-1))/Nfft)^2
5810          Cxy=Cxy/Recolor
5820          Qxy=Qxy/Recolor
5830          Rxx=Rxx/Recolor
5840          Ryy=Ryy/Recolor
5850 !
5860  S22:  Kk=Kk+1
5870          Rxx=Rxx/Nav
5880          Ryy=Ryy/Nav
5890          Cxy=Cxy/Nav
5900          Qxy=Qxy/Nav
5910          Rxy=SQR((Cxy^2+Qxy^2)/(Rxx*Ryy))
5920          Pxy=FNAtan(Qxy,Cxy)*Deg
5930 !
5940          Est1=(Kk-1)*Nband+1
5950          Est2=Kk*Nband
5960          Est=(Est1+Est2)/2
5970          Dph=T95*SQR((1/Rxy^2-1)/Dof)
5980          IF Dph>1 THEN Dph=90
5990          IF Dph<1 THEN Dph=ASN(Dph)*Deg
6000          Wno=Est/Nfft/Delz*1E3
6010          Wlen=1E3/Wno
6020 !
6030          IF V>0 THEN 6190

```

```

6040      PRINT USING 5310;Est1,Est2,Wno,Wlen,Axx,Ayy,Cxy,Qxy,Rxy,Pxy,Dph
6050 !
6060      IF Kk>1 THEN 6110
6070      Axxmax=Axxmin=Axx
6080      Ayymin=Ayymin=Ayy
6090      Wnomax=Wnomin=Wno
6100 !
6110      Axxmax=MAX(Axxmax,Axx)
6120      Ayymin=MAX(Ayymin,Ayy)
6130      Axxmin=MIN(Axxmin,Axx)
6140      Ayymin=MIN(Ayymin,Ayy)
6150      Wnomax=MAX(Wnomax,Wno)
6160      Wnomin=MIN(Wnomin,Wno)
6170 !
6180      GOTO 6860
6190 !
6200      ON V GOTO Autoxx,Autoyy,Cohen,Phase
6210 !
6220 Autoxx: !
6230      A=Axx
6240      IF Kk>1 THEN 6300
6250      PLOTTER IS "GRAPHICS"
6260      GRAPHICS
6270      LOCATE 0,50,50,100
6280      Lgtamin=LGT(Axxmin)
6290      Lgtamax=LGT(Axxmax)
6300      GOTO 6380
6310 !
6320 Autoyy: !
6330      A=Ayy
6340      IF Kk>1 THEN 6380
6350      LOCATE 0,50,0,50
6360      Lgtamin=LGT(Ayymin)
6370      Lgtamax=LGT(Ayymin)
6380 !
6390      IF Kk>1 THEN 6550
6400      Lgtwmin=LGT(Wnomin)
6410      Lgtwmax=LGT(Wnomax)
6420      Ilgtwmin=INT(Lgtwmin)
6430      Ilgtwmax=INT(Lgtwmax+.999)
6440 !
6450      Ilgtamin=INT(Lgtamin)
6460      Ilgtamax=INT(Lgtamax+.999)
6470 !
6480      SCALE Ilgtwmin,Ilgtwmax,Ilgtamin,Ilgtamax
6490      LINE TYPE 3,1
6500      GRID 1,1
6510      LINE TYPE 1
6520      FRAME
6530      MOVE LGT(Wno),LGT(A)
6540      GOTO 6860
6550 !
6560      DRAW LGT(Wno),LGT(A)
6570      GOTO 6860
6580 !
6590 Cohen: !
6600 !

```

```

6610     IF Kk>1 THEN 6690
6620     LOCATE 50,100,0,50
6630     SCALE Ilgtwmin,Ilgtwmax,0,1
6640     LINE TYPE 3,1
6650     GRID 1,.2
6660     LINE TYPE 1
6670     FRAME
6680     MOVE LGT(Wno),Rxy
6690 !
6700     DRAW LGT(Wno),Rxy
6710     GOTO 6860
6720 !
6730 Phase: !
6740 !
6750     IF Kk>1 THEN 6830
6760     LOCATE 50,100,50,100
6770     SCALE Ilgtwmin,Ilgtwmax,-180,180
6780     LINE TYPE 3,1
6790     GRID 1,90
6800     LINE TYPE 1
6810     FRAME
6820     MOVE LGT(Wno),Pxy
6830 !
6840     DRAW LGT(Wno),Pxy
6850 !
6860     NEXT K
6870 NEXT V
6880 !
6890     DUMP GRAPHICS
6900     PRINT PAGE
6910     EXIT GRAPHICS
6920 SUBEND
6930 !
6940 ! *****
6950 !
6960 SUB Fork(SHORT X(*),Y(*),REAL Lx,Signi) ! MODIFIED FROM DENHAM'S PATSY FFT
6970     J=1
6980     FOR I=1 TO Lx                ! SORT IN TIME DOMAIN
6990         IF I>J THEN S10
7000         Rtemp=X(J)
7010         Itemp=Y(J)
7020         X(J)=X(I)
7030         Y(J)=Y(I)
7040         X(I)=Rtemp
7050         Y(I)=Intemp
7060 S10: M=Lx/2
7070 S20: IF J<=M THEN S30
7080         J=J-M
7090         M=M/2
7100         IF M>=1 THEN S20
7110 S30:     J=J+M
7120     NEXT I
7130     L=1
7140 S40:     Istep=2*L                ! FOLD IN FREQ DOMAIN
7150     FOR M=1 TO L
7160         Iarg=PI*Signi*(M-1)/L
7170         Rw=COS(Iarg)

```

```

7180     Iw=SIN(Iang)
7190     FOR I=M TO Lx STEP Istep
7200         Ipl=I+L
7210         Rtemp=Rw*X(Ipl)-Iw*Y(Ipl)
7220         Itemp=Rw*Y(Ipl)+Iw*X(Ipl)
7230         X(Ipl)=X(I)-Rtemp
7240         Y(Ipl)=Y(I)-Itmp
7250         X(I)=X(I)+Rtemp
7260         Y(I)=Y(I)+Itmp
7270     NEXT I
7280 NEXT M
7290 L=Istep
7300 IF L<Lx THEN S40
7310 SUBEND
7320 ! *****
7330 DEF FNAtan(Y,X)
7340     IF X=0 THEN Vert
7350     Ang=ATN(Y/X)
7360     IF X>0 THEN RETURN Ang
7370     IF Y<0 THEN Q3
7380     Ang=Ang+PI
7390     RETURN Ang
7400 Q3:   Ang=Ang-PI
7410     RETURN Ang
7420 Vert: IF Y<0 THEN Down
7430     Ang=PI/2
7440     RETURN Ang
7450 Down: Ang=-PI/2
7460 FNEND
7470 ! *****
7480 END

```

APPENDIX B
Flotation and Fuse Assembly

I. Materials

- A. Knife
- B. Velux 10 lb nylon monofilament fishing leader
- C. Rubber bands, about 3" x 1/4"
- D. Orange wax safety fuse
- E. Flotation collars (Fig. B1)
- F. Pull-wire igniters and instructions

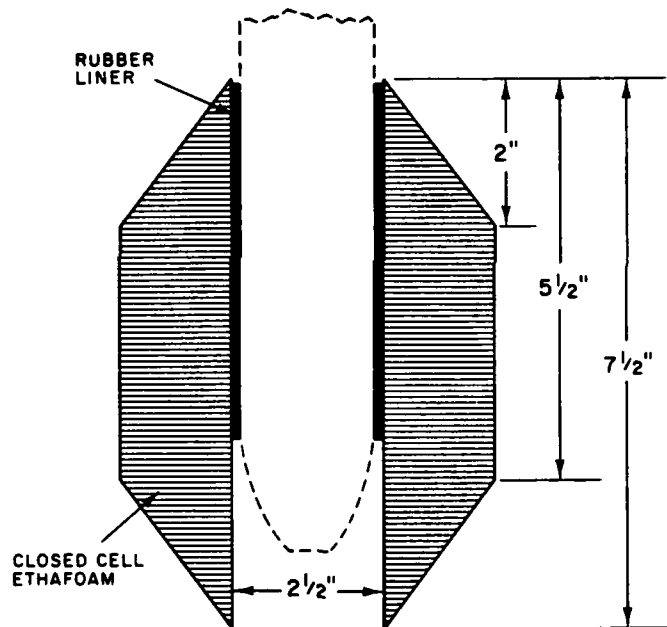


Figure B1. XTVP expendable float, side view cross section.

II. Assembly

- A. Loop two rubber bands together (Fig. B2).
- B. Thread an 8" piece of leader material through both rubber bands, and tie end with surgeon's knot (Fig. B2).

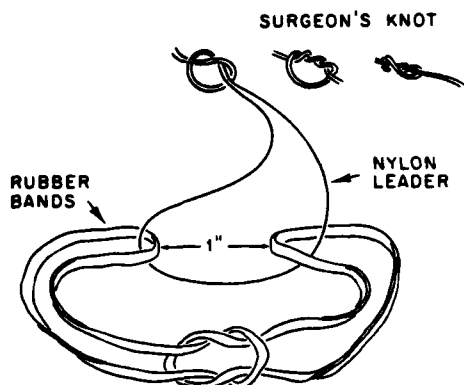


Figure B2.

Leader material threaded through looped rubber bands and tied in surgeon's knot.

- C. Slip rubberband/line assembly over the foam float as shown in Fig. B3.
- D. Prepare fuse by measuring amount needed for desired delay time (orange wax safety fuse burns at 120 sec/yard) plus 5", and cut ends square. Scrape ignitor end to expose powder for reliable ignition.
- E. At the measured point, make a single straight cut in the safety fuse to 1/2 diameter so that knife cut extends into channel filled with fuse burning material, as shown in Fig. B3.
- F. Use a pencil to punch hole into Ethafoam float in longitudinal line with fishline as shown in Fig. B3.

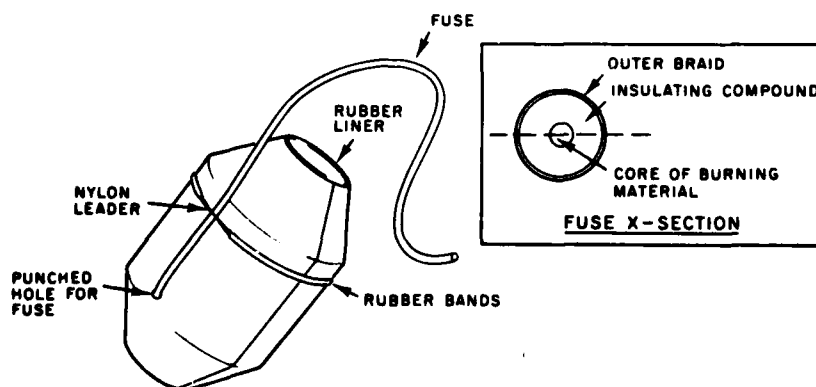


Figure B3. Foam float with rubber band assembly; fuse cut to half the diameter and attached with cut under nylon leader.

- G. Insert fuse into float
 - 1. with end of fuse in hole of float
 - 2. with fishline inserted into cut in fuse so that when fuse burns down it will melt the nylon and release the float halves.
- H. Install assembly in launcher and secure in place.
- I. When ready to deploy, pull wire fuse igniter according to instructions on igniter box, being careful that igniter is pushed well down onto the fuse and that it is not pulled off when the wire is pulled.
- J. The operator should test the method several times to ensure good technique. (Use XBT's to economize.)