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**A Technical Description of an
Acoustic Doppler Based Upper Ocean Profiling System**

by

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Technical Report

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A handwritten signature in cursive script, reading "Robert C. Beardsley", is positioned above a horizontal line.

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1 Abstract

An acoustic Doppler profiler has been designed into a multi-sensor Acoustic Profiler of Ocean Currents system (APOC). All four major components of this data collecting ensemble are microprocessor based units, allowing programmatic flexibility. Various water column, meteorological, and navigation data are recorded in a raw and/or processed form. Plots and listings of processed data are generated and displayed in real-time for use by investigators. Once installed, the system requires only a periodic change of cartridge recording media. The equipment has collected data during five cruises, for a total of approximately 190 days at sea. A hardware and software description of the system is presented. Preliminary technical results are discussed and evaluated.

2 Introduction

This report concerns our experience in designing and integrating a second generation Acoustic Profiler of Ocean Currents system (APOC). The computer-based instrument described here grew out of work performed at the Woods Hole Oceanographic Institution (WHOI) over the last five years with a prototype 300 kilohertz (kHz) Ametek/Straza Division Doppler profiler and WHOI-designed acquisition and processing system. We have recently completed about six months of cruise deployment using the newly developed acquisition and processing system, and a new high powered 115 KHz Doppler instrument from Ametek/Straza. Earlier measurements with the original 300 KHz model were made in a series of five cruises which were part of the Gulf Stream Warm-Core Ring Program, and results have been reported elsewhere. (Joyce, Bitterman & Prada, 1982)

The APOC system includes an acquisition computer which collects a suite of samples consisting of Doppler current profiles, ship's position and heading, surface temperature and salinity, and meteorological measurements. These raw data can be recorded on standard 1/4" tape cartridges, in a format which includes the Doppler returns from the instrument. Another computer system also receives this record and performs preliminary processing to deliver vector-averaged water velocity profiles in real-time. These processed results can also be recorded on 1/4" tape. A third computer provides an interface to, and buffer for, the ship's Serial ASCII Instrumentation Loop (SAIL). The SAIL protocol has been described by Peal & Mellinger, 1981. FORTRAN and assembly language programs running on these various systems coordinate the communication of data between them.

This report will first describe the hardware components and interconnections of the four major subsystems in the APOC system. A description of the programs which execute on each of the computer units is followed by some observations on cruise performance and the difficulties encountered thus far. Finally, the Appendices contains tables of the three tape formats used in this implementation, and summaries of operator commands available in each program.

3 Hardware Description

The APOC system consists of a number of pieces of computer-based hardware and software, connected so as to provide an integrated system. This distributed processing approach means that each component can devote itself completely to the appropriate task. The necessary communications between each subsystem take place under a variety of protocols. In this section, we will describe the hardware of each component, and the interfaces between them.

There are four major hardware subsystems in the APOC scheme. Figure #1 (page 33) is a diagram of the functional blocks comprising the system. Figure #2 is a detailed interconnection schematic of the same hardware. The Acoustic Doppler Profiler (ADP), around which the system is structured, reports directly to the Acquisition System Unit (AU). The ADP generates a water velocity profile by Doppler echo measurements (Rowe & Young, 1979). The SAIL System Unit (SU) collects navigation, ship's orientation, and other information through a separate buffer and SAIL instrumentation loops. These data, taken from sensors scattered about the ship, are also passed to the AU. The AU, in turn, sends ADP, SU and other data to tape and to the Processing System Unit (PU). The PU receives these data records and generates real-time plots and listings of averaged data. These averaged results can be recorded on tape. A detailed description of each of these components follows.

3.1 Acquisition Unit

3.1.1 Computer

The Acquisition unit of the APOC system is an S-100 CP/M Z-80 computer. In addition to the standard console, printer, and disk drive support, it contains other cards to interface with the ADP unit, the PU computer, the SU buffer and the tape drive. There is also a clock/calendar card for inserting time information into the data records. Figure #3 is a block schematic of the AU.

3.1.2 Peripherals

The Televideo 910 console allows an operator to start execution of the disk-resident program. During normal operation, the operator can select modes, make log entries, identify XBT or CTD stations, and monitor program status through the console. Details of console commands and messages are presented in the software section.

The AU printer (C.Itoh 8510P or Epson MX80) maintains a running log of events pertinent to the Acquisition task.

The disk subsystem of the AU consists of two Shugart SA800 8" floppy disk drives connected to the CPU through a CCS2422 drive controller. The executable acquisition program and a text file of ADP parameters are held on the floppy disk.

3.1.3 Tape Drive

The Kennedy 6455 is a 1/4" cartridge, 4-track serpentine drive, with a Pertec standard interface. The unit records at a density of 6400 bits per inch on standard 3M DC300A cartridges. The 600 foot cartridges used in our application will hold as much as 22 megabytes (MB) of formatted data, depending on the record length. There is a 16 kilobyte (KB) maximum record length imposed by both the tape drive and the S-100 controller. For the current APOC configuration, the record length is set at 13.5KB. This yields about 21.8MB of data storage per tape. The drive operates at a 30 inches per second (IPS) read/write speed. This translates to a 24K bytes per second data transfer rate. In the APOC implementation, this means it takes about 1/2 second to transfer a record to or from tape.

3.1.4 Interfaces

Communication with the ADP is over an IEEE-488 interface. The hardware, a D&W Digital IEEE-488+, also contains a parallel port which is used to drive the printer. The card has switch-selectable addressing and handles all the details of the 488 protocol. This interface is capable of relatively fast communications and was selected to match the standard output protocol of the Ametek Doppler unit. Because a 488 interface is structured to allow multiple devices on the same hardware bus, communications between the AU and the PU are also

handled through this card. The interface with the SU is over an RS-232 serial link operating at 9600 baud. Requests from the AU for SAIL module samples are passed over this link.

3.2 Doppler Unit

Briefly, the Ametek/Straza DCP-4400A/115 Doppler instrument consists of a three beam transducer with associated drive circuitry and processing logic. It operates by sensing the Doppler shift, caused by any movement of water-borne scatterers, which may occur in a ping echo. The transducer pings at a programmable rate, for this case once per second. After the ping transmission, the receiver circuits are blanked for a short time to cancel local ship reverberations. The signal tracking logic then begins range gating the returning echos. The frequency of the echo is compared to the reference (transmitted) signal, generating a Doppler shift for each beam, at each depth. These shift values are reported to the acquisition computer for inclusion in the data record.

Ametek has assembled a complete data acquisition and processing system consisting of the Doppler profiler and a Hewlett-Packard HP-85 microcomputer. The HP-85 runs an Ametek developed BASIC program which communicates with the instrument over an IEEE-488 interface. The returned samples can be processed and logged to a DC-100A tape cartridge. In our case, we determined that the relatively slow speed and limited storage capability of the HP-85, coupled with the difficulty of incorporating additional synoptic data from other types of sensors, demanded that we design a dedicated data logging unit for the profiler.

Portions of the following Doppler system descriptions are taken from the Ametek-Straza DCP-4400A/115 technical manual, 1985. Refer to Figure #4.

3.2.1 Main Electronics

The main electronics unit contains the signal processing and computer interface circuitry for the profiler. There are a number of status indicating lamps for monitoring system operation. Signals from the preamplifiers in the Transducer Interface Unit (described below) are further amplified here, then phase compared to the reference signal and digitized. An IEEE-488 interface card provides the communication link for commands and data.

3.2.2 Transducer Interface

The Transducer Interface contains the transducer transmitter power amplifiers and the hydrophone receiver preamplifiers. The unit is equipped with status indicators and an output performance monitor meter. A switch is provided for selection of low or high transmitter power output.

3.2.3 Transducer

The transducer consists of an array of ceramic elements. One element is required for each beam. The 115Khz system considered here utilizes three elements. The transducer head is equipped with a YSI44202 thermistor which is sampled by the control electronics.

For the field work in 1984-85 aboard the R/V Thomas Thompson, a carriage was constructed which allowed the transducer to be supported at the bottom of an open well-tube situated midship. The multi-conductor cable exited the top of this tube, through a water-tight packing, and terminated at the transducer interface unit.

3.3 SAIL Unit

The SAIL subsystem (see figure #5) usually consists of a number of sensors scattered around the ship, which are collecting information such as ship's position through LORAN-C, satellite navigators or a trisponder unit. Other instruments may be sampling ship's attitude sensors, ship's heading from the gyro unit, water surface temperature and conductivity (or a SAIL based CTD instrument), and meteorological data such as wind speed and direction, air temperature, barometric pressure and relative humidity.

These various modules are interrogated by address and they respond to their own address by transmitting the latest sample they have digitized. Since some of the sensor modules deliver relatively long data messages, the SAIL UART in the APOC data logger has to operate at a minimum speed of 2400 baud (240 bytes per second), in order that it can complete all data transactions before the next interval begins (1 second).

However, for the Thompson cruises under consideration here, the available ship's sensors were running at a rate of 300 baud. To account for this mismatch, a separate SAIL buffer was implemented.

3.3.1 SAIL Buffer

The SAIL buffer subsystem of the APOC consists of a CP/M Z-80 computer, with four RS-232 ports. One of these ports supports a standard console for operator control and monitoring. Two of these ports are connected to the ship's two 300 baud SAIL loops. The remaining serial port is attached to the Acquisition system's 9600 baud SAIL loop. The buffer program, written in Z-80 assembly language, simply listens for addresses and the corresponding samples appearing on the ship's loops at 300 baud. These samples are stored until a request from the AU computer is detected. The appropriate module response is then issued on the 9600 baud output loop. Because of the low repetition rate of the 300 baud loops, there are occasional times when a request from the AU for a particular piece of data cannot be satisfied with fresh information. This is somewhat aggravated by the fact that the ship's loop and the AU are operating asynchronously. In these cases, the SU delivers a blanked data format for that specific request.

3.3.2 SAIL Modules

The SAIL concept allows a wide variety of sensor modules to be scattered over relatively long distances. For the deployment under discussion here, the following types of information were collected: Ship's gyro heading, Northstar 7000 LORAN-C, Magnavox Satellite Navigator, Surface Temperature, Surface Conductivity, Wind Speed and Wind Direction. The ship's heading was recorded every ping (1 second) while all other modules were recorded every record (20 pings) within the timing constraints noted above.

3.4 Processing Unit

3.4.1 Computer

The processing unit of APOC is an S-100 CP/M Z-80 computer. The hardware configuration is similar to the AU and contains the standard console, printer, and disk drive support. Other circuitry is included to interface with the Acquisition unit, the plotter and the tape drive. Figure #6 is a block schematic of the PU. The currently available data record from the AU can be requested by the PU. The PU produces printed and plotted output for real-time interpretation, and can record averaged data records on tape.

3.4.2 Peripherals

The Televideo 910 console allows an operator to start execution of the disk-resident program. During normal operation, the operator can select modes and monitor program status through the console. Details of console commands and messages are presented in the software section.

The PU printer (C.Itoh 8510P or Epson MX80) provides a listing of results from selected depth bins. A RAM buffer is attached to the printer input to allow the PU computer to return to its other tasks while the printer plods along. Details of printer output are presented in the software section.

A Zeta-8 multi-pen plotter is attached to the PU computer and can deliver real-time plots as described below. The plotter, which communicates over an RS-232 link, is switch selectable for parameters such as baud rate, communication protocols, pen pressure and scaling. The Zeta also contains an input buffer which shortens the plot data transmission interval.

The disk subsystem of the PU consists of a Shugart SA800 8" floppy disk drive connected to the CPU through a CCS2422 drive controller. The executable processing program and a text file of parameters are held on the floppy disk.

The PU uses the same tape drive as the AU computer: a Kennedy 6455 1/4" cartridge, 4-track serpentine drive.

3.4.3 Interfaces

Communication with the AU is over an IEEE-488 interface. The D&W Digital IEEE-488+, identical to the AU hardware, also contains a parallel port which is used to drive the printer. An additional link with the AU, over an RS-232 port, allows passing of file header information.

4 Software Description

There are four major software elements in the APOC system: acquisition, SAIL buffering, processing and Doppler firmware. The Doppler program, ROM resident, was supplied as an integral part of the Ametek Doppler unit. The remaining software has been developed at WHOI by the authors, in cooperation with persons mentioned in the acknowledgements.

4.1 Acquisition Program

The acquisition program handles the interrogation of, and data collection from, all the sensors and instruments in the APOC system. It requests data from the ADP each time the ADP has completed receiving and digitizing a ping echo. It controls, through the SAIL buffer, the collection of data from the assorted SAIL modules installed about the ship. It maintains and encodes internally available information about the time, date, ping and record number, and operator supplied information such as XBT or CTD station identification or log entries. It formats these data for transmission to the processing system and (optionally) the tape drive. It sends summary status and error messages to the AU printer and console for operator interpretation. These messages are automatically time and position stamped, based on the latest available system samples. The program responds to a set of operator commands, without interrupting its priority task of collecting and transmitting raw data. It presents a user with information about the current status of the Acquisition system's active devices.

4.1.1 Program Flow

The AU program is structured as a polling loop; the status of each device in the Acquisition system is rapidly sampled to determine if some action is required of the program. For example, this action might be transferring a character of text to or from a particular device. The acquisition program begins execution by displaying a sign-on message on the operator console. It proceeds to initialize each device and interface in the system, keeping the operator informed of its progress. The parameter file is read from the disk and used to command the ADP into a particular mode.

Certain file header messages are also read from the parameter file during program startup. These are used as the default answers during entry of the Tape Identifier (ID), Cruise ID, etc. When the program has finished the initialization work, it enters the main polling loop. It remains in this loop until the operator enters an exit command, or (if raw data is being recorded) until the tape cartridge is full. While in this loop, the program constantly checks the status of each device. The ADP is queried first. If the ADP has completed digitizing a ping, the program jumps to the Doppler input routine. The appropriate pointers and counters are incremented, the current date and time are noted, and a burst of samples (520 bytes) is passed from the ADP to the AU. Whether or not this routine has executed, the program then checks to see if there is any SAIL activity required. Each SAIL module has a designated ping number, during which it should be interrogated. The appropriate module address is transmitted to the SU and the received data from that module is packed into its place in the raw array. If the program has reached the end of ping 20 (one record), array pointers are passed to the direct memory access (DMA) circuitry on the tape driver. An alternate buffer is then selected for use during collection of the next record. A check of the communication link with the PU is made and, if it is successful, the latest available record is sent in a burst to the PU. The operator keyboard is tested for any keystrokes which may have occurred since the last pass through the polling loop. Flags are set, based on command keys which are detected, to be acted upon during the program's idle times. A display buffer is checked for characters which may be stacked up for the operator console. If characters are waiting to be transmitted and the display UART is empty, a byte is sent and the buffer indexes are updated. The program flow then proceeds to the top of the polling loop again.

Because of the moderately high (and asynchronous) data rate, it was necessary to have other hardware controllers to handle data transfers on a somewhat independent basis. The tape controller, for instance, is a DMA device which requires only a few passed parameters. The calling routine specifies the location in RAM of the data record, its length and destination. The main program can then continue with other real-time tasks, such as responding to the Ametek unit, the SAIL subsystem, or the console. The DMA logic handles the actual transfer, to or from tape, on its own. This technique implies a need for the alternate data buffers referred to above. There are two tasks which may overlap in time with collection of the next data record: logging the record on tape and sending the record to the processing system. With two data record buffers allocated in memory, the previous record remains available for transmission even as the current ping array is being built. The limit of availability in our case is 20 seconds, the time it takes for 20 pings which, together with some header

information, comprise a 13.5KB record. The program keeps track of these transfers and releases the buffer for use in the next record, when all devices are done using it.

4.1.2 Program Control

There are a number of commands available in the AP2 acquisition program. Also, there is an on-line help facility incorporated into the system. This becomes available by typing an "H" on the acquisition console. During execution of all commands, the program continues operation, even though the console display is suspended. The phrase "COMMAND IN PROGRESS" appears in the upper right corner of the screen (except during Help), as a reminder that the program has suspended display of time, ping number, record number, and error message updates. This phrase disappears and the suspension of display ends when the command being executed is finished. A description of the available commands is attached in Appendix 10.1.1.

4.1.3 Display

During program initialization, messages are displayed on the screen to indicate progress. A summary of the Acquisition system's configuration is sent to the printer and console. Each subsystem is tested. Upon failure, an error message is shown, and the operator is given a chance to correct any problems. The program will then prompt for an action such as trying again or quitting. While the AU program is running, some pertinent numbers are updated and displayed on the AU console (see figure #7). The current program version and compilation date are shown constantly. The Julian day, month, day of month, year, hour, minute and second are updated every second. This system clock information is inserted into every data record. The current ping and record number are updated with each ping. The mode of the Doppler unit is indicated as frequency or amplitude. A line at the bottom of the screen gives prompts for the various commands which are available. There are three other classes of information which may appear: The system message line may display certain errors or status messages as they occur. Upon occurrence, these messages are also echoed to the AU printer log (see figure #8). Thus, even though the console display may be over-written or erased, there is a permanent printed record, with a time and position stamp. A system information entry line is provided for commands which require an operator entry. For example, the <L>og command sets up an edit buffer which appears on the console. The operator may type the log entry on the console without affecting

program execution. To insure against data loss, all potentially destructive commands require a second operator confirmation before they are executed. Lastly, equipment status and program flow messages are displayed mid-screen as they occur. The example figure #7 shows that the printer is offline and that a record is being passed from the AU to the PU. These message displays are transient and will disappear when the associated condition is no longer valid.

4.1.4 Data Output

In addition to the summary information delivered to the printer and console by the AU program, a data record is made available for transmission to external devices (such as the PU) every 20 seconds. A general description of this record follows. Refer to Appendix 10.2.1 for a complete listing of the raw data format.

The file header is a 128 word (256 byte) record which contains parameters and information which will remain constant for each data record in a particular file. The file creation date and time, tape reel number, software version, cruise and ship ID, and various system parameters are included in this record. The items marked with '*' are operator entries. All others are written by the program, and will reflect current conditions during the header creation. All data items in the file header are in ASCII format. A file consists of this header, plus a number of data records followed by an end-of-file mark. For convenience and adherence to an eight hour watch schedule, files have been artificially limited to 19.2MB (1425 records of 13.5KB each, every 20 seconds for 8 hours, with 5 minutes to rewind and change tapes).

The record header for this version is a 256 word (512 byte) data block which contains information which may change at the record rate. All data items in the record header are in ASCII format. With a few exceptions (such as record number, date, time and station ID), this data is taken from various SAIL modules which may be active. A data record consists of this record header, plus a number of ping data blocks (each having a ping header and ping data), followed by an inter-record gap.

The ping header for this version is a 64 word (128 byte) data block which contains information which may change at the ping rate. All data items in the ping header are in ASCII format. This data is taken from various SAIL modules which may be active. A data record consists of the record header defined above, plus a number of pings, each consisting of this ping header and a ping data block.

The ping data block for this version is a 260 word (520 byte) data block which contains the Ametek-Straza Doppler frequency or signal amplitude data. All data items in this block are in binary format. See the Ametek DCP-4400A/115 manual for a description of the data byte formats and status information.

4.2 Doppler Firmware

The Doppler instrument program was supplied by Ametek/Straza and is contained in a set of read-only memory (ROM) chips which are installed in the Main Electronics Unit. The firmware in these ROMS allows simple front panel and more complex remote commanding of the instrument's mode and configuration. In this section, we discuss the initialization of the ADP and the remote selection of a set of operating parameters. The format and communication protocol for Doppler measurements transmitted to the AU are also described.

4.2.1 Initialization

In order to command the ADP into a particular combination of operating conditions, it is necessary to apply a reset command to the unit after the power has been turned on. This command, which can be executed via a front panel button or remotely through the IEEE-488 interface forces the loading of an internal factory-determined table of parameters. After approximately 20 seconds, when this reset sequence has completed, it is then possible to transmit a selected set of command conditions to the unit. These commands, when received by the ADP, take precedence over the factory settings, thus allowing custom operation.

4.2.2 Mode Selection

There are a number of command groups available, and a selection of values within each group. See the Ametek technical manual for a complete listing. As an example, the profiler can be commanded to operate in frequency or amplitude mode. In the frequency mode, data values reported are comprised of 64 range-gated bins of Doppler shift measurements for each beam. In the amplitude (or AGC) mode, the values are measures of the echo signal strength from each of the 64 bins for each beam. Additionally, the profiler can be operated in bottom track

mode. In this case, values for ship-relative bottom velocities are reported in the first bin of the data transmission. Bottom tracking is not used in the present APOC version, due to the varying ping rate produced by the profiler while in this mode. Other commands allow selection of ping rate, signal detection thresholds, range bin widths and signal tracking gains, to name a few.

A limitation during this phase of initialization is that, in the present design, there is no capability for the ADP to report its current operating conditions. Without verification of the proper acceptance of these commands, the controller (in this system, the AU) cannot know if the instrument has entered the correct mode. While certain improperly received parameters (such as ping rate) will be obvious to an observer, others will not. Occasionally it has been noted that a particular parameter had been incorrectly set. In these instances, a manual restart of the APOC system is necessary.

4.2.3 Communication

The ADP, as usually operated in the present APOC configuration, delivers 64 bins of range-gated Doppler shift measurements for each of its three 115Khz beams. These data are contained in a 520 byte binary block which is transmitted to the AU on request, over the IEEE-488 interface. See the Ping Data Block in Appendix 10.2.1 for details. The ADP automatically generates pings and collects echo measurements at the rate which has been commanded. It buffers the results internally until the next ping's digitizing has been completed. If the AU has not requested the transmission of data by this point, the ADP's buffer is cleared and replaced with the new results. The data block starts with a specially coded word to enable frame synchronization by a receiving device. The next word can contain the ship's heading, if the ship's gyro has been connected through the ADP port provided. This has not been implemented in the APOC system, since gyro information is available at the required rate through the SAIL loop. There are then two bytes of bottom track data for each beam. These are padded with zeros unless bottom track mode has been commanded for the ADP. There follows 2 bytes for each beam, for each of 63 range bins. Each byte pair is formed from a single 12 bit Doppler shift value. The extra 2 bits in each byte are a status bit and a mode bit. The mode bit indicates whether the ADP is in bottom track or profile mode. The status bit is used as a data quality flag. The instrument has, as part of its command set, the means to set a signal strength reference level. When the detected echo strength is less than this reference, the status bit is set to indicate the presence of low quality samples. The ADP determines what the state of this flag should be, by measuring the echo signal strength from each sample and comparing it to the

signal-to-noise threshold which has been commanded through the AU. This flag can be tested by data processing routines to determine if signal quality was above a specific level. When this status bit has been set to indicate "bad" data, the ADP also blanks the bin sample in question, by overwriting it with the most recently available good sample. Due to this blanking, the APOC system is generally operated with a very low signal threshold value. This tends to thwart the blanking scheme and allows a user decision to be made (based, in part, on the quality flag) as to whether or not the data is reliable. The bin data bytes are followed by another uniquely coded word which serves as a trailer synchronizing byte. Finally, two more bytes are sent which can hold a variety of information on a rotating basis. For example, approximately every seven pings these bytes contain the temperature measurement from the thermistor installed in the transducer head.

4.3 Processing Program

The processing system runs a display program which retrieves data from the Acquisition computer, decodes this data, scales and averages it, and produces hard-copy listings, plots, and tapes. Data display is provided for analysis purposes as well as quality control of the data being collected on tape. Data is typically averaged over five minute intervals, giving some smoothing without obscuring features or producing an overwhelming volume of data output. The current averaged data record length is 7200 bytes, normally representing 15 acquisition data records of 13472 bytes each. The acquisition format and the averaged data record format are described in Appendices 10.2.1 and 10.2.3 respectively.

Currently, only Doppler frequency data is processed by the PU, and AGC mode (or amplitude) data is ignored by the processing system. For cruises on which raw time-series data is recorded directly to magnetic tape by the AU, the processing program can also accept data from a tape drive for post-processing at sea or ashore.

4.3.1 Program Control

To allow for the flexibility of the Doppler unit and various SAIL configurations, the processing program is controlled at startup by a set of parameters contained in an ASCII disk file. A sample parameter file is shown in figure #9. This file is easily edited, and is printed at program startup for data documentation purposes. During a processing run, further control is supplied by 'break keys' which allow

modification of some parameters and direct control over program flow. The user can change the geographic mapping area, change the navigation method selected for ship's velocity calculations, request new plot pages to be drawn, stop all output to the plotter, or change the vector correction scheme. An end-of-tape protocol can also be requested, which writes an end-of-file to the current tape and begins the next output tape with a file header. See Appendix 10.1.3 for an listing of these commands.

4.3.2 Navigation Processing

Three navigation streams can be recorded; two LORAN systems and a transit satellite navigator (SATNAV) were available on the R/V Thompson cruises. Because of timing considerations in the SU, only one LORAN system's data was actually collected. Unused fields in the navigation data streams are filled with blanks by the AU and ignored by the processing software. LORAN latitude and longitude are averaged as reported, and time delays, station repetition rates, and signal to noise ratios are stored for post-processing of the navigation data. Ship's velocity for the averaging period is calculated from reported LORAN positions. The SATNAV system reports calculated (dead reckoning) positions based on previous fixes and ship's velocity information. These positions are stored along with fix information. The ship's position reported during the last fix and the time elapsed since that fix are recorded for reprocessing of satellite navigation data. SATNAV ship's velocities are converted from knots to meters per second, averaged and stored.

4.3.3 Other Data Streams

The ship's heading is averaged from data reported in each ping, as is the temperature of the Doppler transducer. For each record, SAIL temperature and conductivity are calculated from frequency counts reported by the underway thermosalinograph. Wind data relative to the ship are corrected for ship's heading for each record, and vector-averaged over the specified averaging period.

4.3.4 Doppler Data

The Doppler values are decoded, corrected for transducer alignment and converted to ship-relative north and east velocities before being accumulated. User-supplied sound velocity and transducer alignment corrections are used in the conversion. Transducer alignment corrections are chosen at program startup, with three angles supplied in the parameter file: the rotation about a vertical axis, a fore-aft axis (pitch), and an athwartship axis (yaw).

4.3.5 Data Output

The output segment of the processing program receives the averaged data, encodes it and writes it to tape in formatted ASCII records. Before the data is displayed, corrections for ship's motion are made to the water velocities. Corrections can be made using ship's speed from one of the navigation data streams, or relative to a vertical average of a user-selected range of bins. All velocities are output in meters per second.

4.3.6 Display

The data listing (see figure #10) includes the start and end date, time, and acquisition system record numbers of the data included in the average period. SATNAV and LORAN mean latitude and longitude are reported. The ship's heading and ship's velocities north and east (in meters per second), and the wind speed and direction are followed by satellite fix information. Transducer temperature, SAIL temperature, conductivity and salt are listed. This information is followed by corrected water velocity data; bin number, mean depth of bin in meters, water velocity north and east, vertical water velocity, and the number of good pings included in the average for the bin. A flag indicating the method of correcting the data is shown, and the correction applied is listed.

Up to four pages of plots are created by the real-time program. Refer to figures #11, #12 and #13. A vector plot displays the water velocities (corrected for ship's motion now) from two user-selected bins, along a time axis. A scalar plot of temperature, salt, latitude and longitude along a time axis is provided. Shear profiles display data from all the bins along time and depth axes. Geographic mapping

of corrected vectors from one or two bins is done in Mercator projection.

4.3.7 Programming Notes

This program is written in MICROSOFT's F-80 FORTRAN, with some MACRO-80 assembly language routines. It is linked with Digital Research's LINK-80, which allows larger program module size by reducing its internal buffer size. Plotter interface routines are from Nicolet Zeta's FORTRAN plot library. Because of its size, the program is composed of segments which are swapped into memory by an in-house background program, OVLOAD (Zani, 1983). Data is shared by the segments through the FORTRAN "common" block. OVLOAD reserves space for the common area, loading each segment beyond the required memory.

4.3.8 Program Segments

The first segment to load is program GO. GO initializes program variables and reads the control parameters from an ASCII disk file, then calls for program ADOPI, which determines if plot pages are to be initialized. Plotting can continue on a previously drawn axis, if desired. If new plot pages are to be drawn, control is transferred to program API, which draws the axes and then calls program APOC, the main processing segment. Program APOC executes a loop consisting of data input, decoding, and accumulation, for a user-specified number of records. Programs APOC and APT then swap in and out continuously until the user interrupts or until the end of the time axes on the plots has been reached and new plot pages need to be initialized.

4.3.9 Timing

Unlike the acquisition program, the processing system does not keep track of elapsed time during processing. While the AU provides a data record at fixed intervals, the PU requests new records only when ready to process them. Two parameters in the start-up file of the processing program control the timing of the acquisition computer, setting the amount of time needed by the processing system to handle each record, and the delay needed at the end of each averaging period for data output before a new record can be accepted. If these parameters do not provide enough time for the PU to complete processing before a new

record is offered by the AU, the AU generates warnings to indicate that data will be lost.

4.4 Post-Processing Programs

4.4.1 Averaged Data Tapes

The averaged data tapes may be redisplayed and reprocessed by several programs available on the CP/M Z-80 processing unit, on Microvaxes, or on DOS IBM-PC clones. Program APTSP reads the averaged tape, optionally recalculates ship's velocity corrections using a user-specified method (navigation data or zero-velocity bins), creates vector plots along a time axis, and lists the data. This data may also be saved to disk files for further processing. Program APAVE averages tape data over any time period, for display or file storage.

4.4.2 Time-Series Tapes

Data tapes created by the Acquisition unit can be read by the processing unit and handled as real-time data. This capability is primarily used for development work, but also provides an alternative mode of operation at sea.

Raw time-series data tapes can also be processed on shore using a Hewlett-Packard 2100 series computer operating in the RTE-IVB environment. Original data tapes are copied and logged using program APCOP, which provides 'clean' tapes for further processing and provides information on any problems with the original data tapes. Several diagnostic programs are available for problem data. One can display raw Doppler data, data quality bits, velocity values, LORAN data and time delays. Program TRSTS simulates APOC data logger output to the CP/M system, using a raw data tape on the Hewlett-Packard and an RS-232 connector to the microcomputer.

4.4.3 Processed Data Tapes

APOC data from raw tape can be processed, time-averaged and written to tape on the H.P. using program APAGA. Appendix 10.2.2 describes the tape format. Several programs are available for display of averaged data on the H.P. Current vectors can be plotted on time or depth axes, or on Mercator charts. Velocity components can be plotted against depth or time. Program AVTSP calculates and lists salt using the Seabird sensor data, and program SHIFT recalculates current vectors using a correction to the transducer offset angle.

4.5 SAIL Programs

The SU subsystem program provides the AU with samples from the instrumentation modules scattered around the ship. Because of SAIL module baud rate restrictions, and the asynchronous operation referred to above, it was necessary to implement a buffer for these data.

4.5.1 SAIL Buffer

The SAIL buffer program contains a list of modules pertinent to a specific cruise configuration. This list contains the data format for each module. The program monitors two 20 milliamp (ma) SAIL loops for an addressed interrogation of one of these modules. When it detects an address of interest, it listens for the data transmission from the interrogated module, and copies the information to an internal memory buffer. The program also simultaneously monitors another serial port, which is connected to the AU. The AU issues, on its own schedule, requests for specific pieces of SAIL data. When these are detected by the buffer program, the latest available sample from the corresponding module is sent to the AU at 9600 baud. The memory buffer for that module is then filled with blanks. This blanking is done because another request may come from the AU for that same module's data, before the module has actually sent a new sample to the buffer. Programs which access the data records built from these samples will then be aware that a new sample was not available at that time. Console support for monitoring the buffer program is provided. Visual indication of activity on all three monitored ports is displayed. Appendix 10.1.2 contains an explanation of the SAIL program's commands.

4.5.2 SAIL Modules

All SAIL modules are each running a custom program on an 8748 micro-controller. There are various types of module firmware and hardware configurations for functions such as voltmeters, counters, synchro-to-digital converters, etc. A module can be switch-programmed to respond to a particular address, and generally has some flexibility concerning measurement range and scaling factors.

5 Cruise Evaluation and Results

The APOC system, in the configuration discussed here, was first fielded in November, 1984 on a five week Tropic Heat Equatorial cruise. Since then, the system has undergone a number of relatively small modifications. These have been related to upgrading programs with additional features, adding or deleting sensors according to availability, and correction of software bugs. As of this writing, the system has performed well during five cruises in the Pacific on the R/V Thompson, for a total of 190 days at sea. In this section, we evaluate the technical performance of some of the components selected for this system.

5.1 Computers

5.1.1 Reliability

The major source of troubles for the computer systems has been mechanical failure. The moving parts are simply wearing themselves out. Floppy disks, disk drives, printers and the plotter have all experienced failures when subjected to the combination of the at-sea environment, fluctuating supply power, and around-the-clock usage for weeks or months at a time. An on-board supply of spare parts and subsystems has prevented any significant amount of down-time.

5.1.2 Enhancements

The computer portions of the APOC system were, for the most part, integrated from commonly available chassis, power supplies, disk and tape drives, and function boards. Only one type of board, the math co-processor, had to be designed and constructed in-house. Some devices, such as the plotter and tape drive, were purchased with software drivers. In some cases, these drivers, although not directly usable for our task, eased the generation of our custom program routines. All three computer systems are essentially identical, but

contain certain unique function boards for their particular place in the system. The modular approach used for this system proved very useful during initial development and subsequent debugging and enhancement. Modification of some aspect of the system generally requires changes to only one of the programs, thereby speeding and simplifying the process.

5.1.3 Design Limitations

The Acquisition unit and the SAIL unit proved to be more than fast enough to handle a continuous, uninterrupted stream of real-time data. There appears to be enough (memory space and execution time) overhead left for significant code additions, should these be desirable or necessary. The Processing unit, on the other hand, is already groaning under the weight of its rather large FORTRAN program. A software implemented delay structure is currently in use to alleviate this problem: the Processing unit sends a delay value to the AU whenever a new data record is received. The value is empirically determined during program development. During the averaging period (typically 5 minutes) the PU is able to finish its routines before the next record is available. Therefore, the delay value is zero. However, at the end of the average period, the PU cannot complete its tasks in time, i.e.: process results, write to tape, plotter, printer and screen. The delay value passed to the AU causes the AU to suspend data collection until the PU is available to again receive data records. This intermediate solution will be discarded in the next generation of faster processing hardware.

5.2 Doppler

5.2.1 Reliability

The Ametek-Straza DCP-4400A/115 Doppler current profiler incorporated into this system has performed well in the six months the system has been to sea. The unit has been technically reliable for this period, with occasional down-time for minor issues, such as corrosion on the edge connectors of the electronics cards. The unit has recently evidenced an intermittent failure which occurs when the electronics are first powered on. By this writing, the problem had been resolved by Ametek personnel.

5.2.2 Data Quality

Doppler returns are fairly consistent with each other from ping to ping, in an approximate depth range of 20 meters to 300-350 meters, and there is a steady decrease in signal strength of the returns with increasing range or depth. The maximum range is dependent on a number of factors such as the amount of scatterers in the water column, and the acoustic environment of the ship/platform. For example, in a number of instances, there appeared to be a diurnal shift in the maximum depth of Doppler penetration. This is assumed to be a result of biological scatterers migrating through the water column.

6 Summary

A second generation APOC instrument system has been successfully implemented and refined following several extended cruises. The hardware components, which were selected from off-the-shelf readily available parts and integrated in-house, were flexible enough to form the four different functional blocks which comprise the system. The multi-processor design approach used here has eased the task of fabricating a system which required both rapid data acquisition from several asynchronous devices, and real-time presentation of data in an easily understood and appropriate format.

Software, which was based on earlier work with a prototype profiler, was redesigned and restructured in a more modular fashion to allow simplified enhancements or modifications in the future. The operator interface has been made more friendly, to enable deployment on cruises of opportunity without intimate technical support.

Experience with hardware failures of moving parts during these lengthy (five to eight weeks) cruise experiments points toward PROM based program storage and, perhaps, graphic CRT displays of data to obviate or lessen the need for certain mechanically based system components. A modularized spare parts supply appears to be a necessity. There is a distinct need for the Doppler instrument to be able to report its current status and mode, considering the multitude of command combinations which may be requested by an investigator. More computing power is needed for the real-time processing task, in order to keep pace with the bulky and rapid stream of Doppler data available from the instrument. This would allow uninterrupted collection of averaged time-series data, which the present hardware cannot maintain.

The semi-processed data storage format written by the processing system has significantly reduced the amount of post-cruise work required in order to obtain meaningful results, although the possibility exists for contamination or loss of the raw measurements if programming errors are introduced or have not been detected in the processing unit. A storage reduction factor of approximately thirty (compared to storing raw data) has been realized with this technique.

7 Acknowledgements

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8 References

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9 Figures

- Figure 1: APOC system block diagram
- Figure 2: APOC system interconnections
- Figure 3: Acquisition unit block diagram
- Figure 4: Ametek DCP-4400A/115 block diagram
- Figure 5: SAIL unit block diagram
- Figure 6: Processing unit block diagram
- Figure 7: Acquisition unit console display
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9.1 APOC system block diagram

9.2 APOC system interconnections

9.3 Acquisition unit block diagram

9.4 Ametek DCP-4400A/115 block diagram

9.5 SAIL unit block diagram

9.6 Processing unit block diagram

APOC II Data Server
V2.34 02/04/86 ACZ

041 02/10/86 14:38:47.29

COMMAND IN PROGRESS

Ping 15
Record 0394

FREQUENCY Mode

PRINTER NOT AVAILABLE
Transferring Data...

Your command is C. Enter DATE & TIME: MO/DA/YR HR:MI:SE

041 02/10/86 14:35:24 Log entry: The ship is approaching CTD station #087

Alarm Break Clock End File Help Log Mode Redraw Station Tape

9.7 Acquisition unit console display

APOC II Acquisition Log Sheet

Acquisition ID: GA11
Track ID: 0082
Cruise ID: GALE - ATKINSON

Doppler ID: DCP4400115
Data logger ID: QT SYSTEM

Comment 1: STARTING UP NEW TAPE FOR SECOND TRACK
Comment 2:

System parameters: 0512 0128 0520 20
Doppler parameters: 12 19 26 32 41 49 57 68 73 81 89 12 24 32 36 45 57 66 71 18 16 28 48
Doppler cmd groups: 01 02 03 04 05 06 07 08 09 10 11 14 15 16 17 18 19 20 21 26 27 28 31

SAIL modules online: 40171 00003
Software version: V2.33 01/07/86 ACZ

Day	Date	Time	Position	Type	Description
012	01/12/86	12:41:46	* = OLD NAV DATA.	System:	OPENING ACQUISITION FILE.
		13:18:00	N324980 W 792894	Log entry:	FINISH CONSEC 28
		14:00:18	* N324980 W 792894	Log entry:	ON 29
		14:42:18	N324145 W 791926	Log entry:	ON 30
		15:41:37	N323932 W 791653	Log entry:	NEXT TO BUOY 6
		16:25:50	N323746 W 791343	Log entry:	ON STATION 31
		16:38:41	N323774 W 791355	Log entry:	OFF STATION 31
		17:10:22	N323324 W 790840	Log entry:	ON STATION 32
		17:50:50	N323132 W 790554	Log entry:	ON STATION 33
		18:06:02	N323110 W 790525	Log entry:	OFF STATION 33
		18:27:56	N322912 W 790296	Log entry:	ON 34
		19:12:30	* N322912 W 790296	Log entry:	ON STATION 35
		19:51:54	* N322912 W 790296	Log entry:	ON STATION 36
		20:31:33	N322310 W 785402	Log entry:	ON STATION 37
		20:43:07	N322292 W 785460	Log entry:	SHIP DRIFT 110 AT .5 T01, KNOT
		21:22:52	N322091 W 785173	Log entry:	ON STATION 38
		22:31:43	N321899 W 784992	Log entry:	ON STATION 39
		22:39:30	N321894 W 784988	Log entry:	OFF STATION 39
013	01/13/86	00:13:02	N321683 W 784817	Log entry:	ON STATION 40
013	01/13/86	03:48:21	* N320783 W 783573	System:	CLOSING ACQUISITION FILE. LAST RECORD #2377

9.8 Acquisition unit printer log

9.6	Tracker time constant:	(in milliseconds)	(f5.1)
9.6	Bin width interval:	(in milliseconds)	(f5.1)
30.0	Ametek beam angle:	(degrees)	(f5.1)
1	Average only good data:	1=only good, 0=all data	(i1)
0	Bottom track mode:	1=on, 0=off	(i1)
4.3	Transducer depth:	(meters)	(f5.1)
1.00	Velocity vector scale:	(inches/meter/sec)	(f6.2)
1.00	Shear scale:	(inches/meter/sec/bin)	(f6.2)
1.00	Time scale:	(inches/hour)	(f6.2)
5.00	Temperature full range scale:	(degrees c)	(f6.2)
5.00	Conductivity full range scale:	(mmho)	(f6.2)
2.00	Salinity full range scale:	(ppt)	(f6.2)
1.00	Latitude full range scale:	(degrees)	(f6.2)
1.00	Longitude full range scale:	(degrees)	(f6.2)
41.0	Minimum latitude for mapping:	(degrees)	(f5.1)
140.0	Minimum longitude for mapping:	(degrees)	(f6.1)
1.0	Latitude map scale:	(inches/degree)	(f5.1)
15	Number of records to average:	(1-99)	(i2)
64	Deepest bin to process:	(bin 2-64)	(i2)
0	Inter-record delay:	(0-255)	(i3)
200	Inter-averaging period delay:	(0-255)	(i3)
2	Number of maps:	(0-2)	(i2)
180.00	Transducer offset angle:	(0-359.99)	(f7.2)
06,33	Range bins to draw vectors for:	(bins 2-63)	(2(1x,i2))
2	Vector correction:	0=none, 1=nav, 2=avg bins	(i2)
3	Ships velocity calc & map nav:	1=11, 2=12, 3=sat	(i2)
47,51	Bin range for vector corr:	(2-64)	(2(1x,i2))
1.85	Transducer vertical angle:	(degrees)	(f7.2)
0.0	Transducer athwartship angle:	(degrees)	(f7.2)
180.00	Transducer alongship angle:	(degrees)	(f7.2)
1020.	Maximum vertical water velocity:	(meters/sec)	(f6.2)
1	Ping data subsample interval:	(1-8)	(i1)
1500.0	Sound velocity for vector calculation:		(f7.2)

9.9 Processing unit parameter file

velocities are corrected by ships navigation
 velocity corrections N: 1.6338 E: -1.8170
 Start rec, year, day, time 229 86 16 330:26
 End rec, day, time 243 16 335: 6
 LORAN 1 Mlat,Mlon 0.0000 0.0000
 LORAN 2 Mlat,Mlon 32.3270 -78.8461
 SATNAV Mlat,Mlon 32.3264 -78.8517
 Position for the Humans 32 19.6 78 51.1
 Ship vel north, east 1.6338 -1.8170
 Wind N, E, Avg ships heading 1.125 1.319 313.882
 Rel wind speed 1.7338 Dir 95.67 Abs dir 49.55
 For bin 3 Standard deviation N,E,U = .524 .546 .264
 Last fix, Delta time,Elev,Iter... 32.2782 -78.7862 1 21 0 0
 Trans temp, SAIL temp, Cond..... 22.8000 22.8842 52.3817 SAL 36.1754

BIN	MDEPTH	UNORTH	VEAST	UVERT	NPINGS
1	0.000	0.000	0.000	0.000	0
3	9.877	.246	-.221	.133	300
5	16.112	.227	-.169	.087	300
7	22.347	.159	-.105	.085	300
9	28.583	.136	-.188	.078	300
11	34.818	.144	-.208	.072	300
13	41.053	.022	-.308	.092	300
15	47.289	.083	-.433	.091	300
17	53.524	.135	-.516	.060	298
19	59.760	.222	-.413	.082	299
21	65.995	.232	-.506	.071	298
23	72.230	.221	-.551	.061	289
25	78.466	.191	-.292	.017	206
27	84.701	.280	-.377	.080	197
29	90.937	.274	-.219	.013	147
31	97.172	.310	-.167	.013	158
33	103.407	.259	-.283	-.003	125
35	109.643	.257	-.197	-.025	118
37	115.878	.183	-.158	.021	115
39	122.113	.224	-.119	-.017	137
41	128.349	.166	-.223	.078	115
43	134.584	.282	-.169	.046	123
45	140.820	.515	-.542	-.033	197
47	147.055	.946	-.526	-.048	165
49	153.290	.866	-.833	-.160	188
51	159.526	.421	-.478	.003	274
53	165.761	.222	-.101	.138	296
55	171.997	.351	-.073	.193	206
57	178.232	.580	-.170	.034	44
59	184.467	.259	-.105	.492	4
61	190.703	0.000	0.000	0.000	0
63	196.938	0.000	0.000	0.000	0

9.10 Processing unit printer log

VSCALE (INCHES/METER/SEC) = 1.000

9.11 Processing unit plotter output 1

9.12 Processing unit plotter output 2

9.13 Processing unit plotter output 3

10 Appendices

10.1 System Commands

Each of the component programs of the APOC system has a set of operator commands which are available for use through the system consoles. In this Appendix, the three sets of commands are listed and described.

10.1.1 Acquisition Unit Commands

Alarm	Invoke by typing an "A". Alternately enables and disables the console's alarm bell. Only the audible bell is affected. Full program operation continues and all messages are still reported to the console screen and the printer.
Break	Invoke by typing a "B". This command is ineffective in the current hardware implementation. However, no ill effect is produced if it is executed. It resets the SAIL loop.
Clock	Invoke by typing a "C". This command allows you to set the acquisition system's clock. This is the source for recorded and printed time/date information. The program will ask for confirmation, then prompt you for the MOnth/DAY/YeaR and HouR:MIminute:SEcond. Range checking is done on your entries before they are accepted. For examples, the month entry must be between 1 and 12 inclusive, and the minute entry must be between 0 and 59 inclusive. Any characters may be used for the date and time separators, since the program discards those characters. That is, you are not required to use the "/" and ":" to separate your entries. Complete your entry by typing a <RETURN>. For consistency, please use GMT time. If you make an improper entry, (for instance, hours greater than 23) the console will display "No entry" and the clock will NOT be updated. If your entries are within reason, the program will indicate "Time entered", a line will be

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printed on the acquisition log sheet with the old and new times, and the time/date WILL be updated.

- End Invoke by typing an "E". If the Acquisition system is not configured to write raw data to tape, this command terminates the current run of the acquisition program, allowing you to make a new header entry. The program asks for confirmation. If you confirm that you want to exit, the program continues normal operation until the end of the current record. That is, until ping 20. The program then recycles to its starting point, allowing you to exit completely or restart again with a new header entry.
- File Invoke by typing an "F". If the Acquisition system is configured to write raw data to tape, this command closes the current tape file by writing an end-of-file mark on the tape. The program asks for confirmation. If you confirm that you want to close the file, the program continues normal operation until the end of the current record. That is, until ping 20. The program then recycles to its starting point, allowing you to exit completely or restart again with a new file header.
- Help Invoke by typing an "H". This command displays a brief summary of the available acquisition commands. The commands on these pages are listed and described.
- Log Invoke by typing an "L". This command allows you make a (up to) 40 character log entry on the acquisition system's printer page. The program asks for confirmation. While entering your text on the display console, you may edit the line by using the <BACKSPACE> key and typing over your previous text. Complete your entry by typing a <RETURN> when done. This text is ONLY sent to the printer, and is NOT RECORDED on tape. There is a routine automatically invoked by the program which stamps your log entry with the Julian day and the date (if the day has changed), the time and the latest available position from the SATNAV or LORAN. This feature means that you can use the Log command to maintain a semi-automatic cruise event log. For example, by typing "100 year

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wave engulfs ship", the date, time and position of this event will automatically be added to the log, along with your text.

- Mode Invoke by typing an "M". The program gives you three choices: FREQUENCY mode, AMPLITUDE mode, or NO CHANGE. Although this command is supported by the acquisition system, the AMPLITUDE mode is not supported by the current version of the processing software. If you should inadvertently switch to the AMPLITUDE mode, immediately switch back again to FREQUENCY mode. Recorded processed data will be meaningless in AMPLITUDE mode. The current mode is indicated on the display console.
- Redraw Invoke by typing an "R". This command simply erases the console display and redraws it. This allows the operator to rid the screen of old error messages, so that s/he can determine that a message or error condition has occurred since the last time they looked at the display. It has no effect on the printed log output, or on any other aspect of program operation.
- Station Invoke by typing an "S". This command allows the operator to enter (or clear) a Station Identifier mark. If you answer "Y"es to the confirmation question, you will be allowed to make an ID entry. If you answer "N"o, any existing Station ID will be cleared away. The ID can be up to six characters. They can be any printable characters. Use the <BACKSPACE> key and type-over for editing, as for the Log command above. When you make an entry, it is sent to the acquisition system's printer log. It is also inserted into the current record on tape if raw data are being recorded. It continues to appear in each and every record on raw tape, until you clear it using this same "S"tation command. For example: The ship comes on station for CTD number 72. The operator presses the "S" key to make a Station ID entry, and answers "Y"es to the confirmation question. S/he enters "CTD072" at the keyboard, and terminates the entry with a <RETURN>. The program makes a log entry on the printer, and starts to insert this ID into every raw tape record. When the cast is complete and the ship is leaving the station, the operator again

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types an "S", this time entering a "N"o to answer the confirmation question. The Station ID, "CTD072" is cleared and is not inserted into any further raw tape records. In post processing, all records taken while on that station will be tagged with "CTD072".

Tape

Invoke by typing a "T". If the Acquisition system is configured to write raw data to tape, this command ends the current tape reel by writing two end-of-file marks on the tape. The program asks for confirmation. If you confirm that you want to close the file, the program continues normal operation until the end of the current record. That is, until ping 20. The program then rewinds the tape to the load point and prompts for insertion of a fresh tape.

Appendix 10.1.2

10.1.2 SAIL Unit Commands

- Redraw** Invoke by typing an "R". This command simply erases the console display and redraws it. This allows the operator to rid the screen of old error messages, so that they can determine that a message or error condition has occurred since the last time they looked at the display. It has no effect on any other aspect of program operation.
- Crash** Invoke by typing a Control-C. (Hold the <CONTROL> key down while pressing the "C" key) This command terminates the current run of the SAIL program. The program asks for confirmation. If you confirm that you want to exit, the program exits immediately.
- reStart** Invoke by typing an "S". This command restarts the SAIL buffer program from the beginning, allowing a flush of all buffers and initialization of hardware ports. The program recycles to its starting point, allowing you to exit completely or restart again.

Appendix 10.1.3

10.1.3 Processing Unit Commands

CTD	Invoke by typing a "C". If the APOC system is configured to support a CTD, the processing program changes to CTD mode.
End	Invoke by typing an "E". End the current program run. The program asks for confirmation, then prompts for ending the current tape and the current run.
Map	Invoke by typing an "M". Change mapping scales on the plotter. The operator is prompted for new map origin coordinates.
Navigation	Invoke by typing an "N". Change the navigation method used for plotting and vector correction.
Redraw	Invoke by typing an "R". Redraw the plotter initialization pages on next output.
Tape	Invoke by typing a "T". End the tape currently in use by writing two end-of-file marks on the tape.
Vector	Invoke by typing a "V". Change the vector correction method used by the program.

Appendix 10.2

10.2 Tape Formats

There are two defined tape formats for data collection at sea. The inter-record gap produced by the Kennedy 6455 drive is approximately 1.2" of tape, so the actual formatted capacity of a tape is heavily dependent on record size. 128 byte records would yield about 750 KB formatted storage, roughly a factor of 30 less than the potential maximum of 22MB using 16KB records. The problem is typical of this type of storage. The raw data format collects 13,472 bytes every twenty seconds. The 600 foot tapes in current use will hold, in the best case, approximately 22 MB. Therefore, the raw data tapes can hold 9 hours of data. This is typically limited to 8 hours (one watch) for convenience. The processed data format collects 7,200 bytes every 5 minutes. Therefore, the processed data tapes can hold 8.5 days of data. This is typically limited to a few days to minimize any potential data loss. The tape formats are described specifically in the following sections.

Appendix 10.2.1

10.2.1 Raw Data Format

Raw Data File Header Format

WORD	DESCRIPTION	BYTES	RANGE
1-2	DAY OF YEAR	4	<0001-0366>
3	MONTH	2	<01-12>
4	DAY OF MONTH	2	<01-31>
5-6	YEAR	4	<1984-1989>
7	HOUR	2	<00-23>
8	MINUTE	2	<00-59>
9	SECOND	2	<00-59>
10-11	TAPE REEL ID	4 *	<ANY CHRS>
12-13	TRACK ID	4 *	<ANY CHRS>
14	TAPE FILE ID	2	<00-99>
15-19	UNDEDICATED	10	
20-29	CRUISE ID	20 *	<ANY CHRS>
30-34	DOPPLER ID (XXX=115 or 300)	10	<DCP4400XXX>
35-39	LOGGER ID	10 *	<ANY CHRS>
40-59	COMMENT LINE 1	40 *	<ANY CHRS>
60-79	COMMENT LINE 2	40 *	<ANY CHRS>
80-81	RECORD HEADER BYTE SIZE	4	<0256-8192>
82-83	PING HEADER BYTE SIZE	4	<0032-8192>
84-85	PING DATA BYTE SIZE	4	<0520-????>
86	PINGS PER RECORD	2	<01-99>

Appendix 10.2.1

Raw Data File Header Format (continued)

87	TRANSMIT PULSE WIDTH CODE	2	<08-14>
88	RANGE BIN SIZE CODE	2	<17-21>
89	PROFILER OPERATING MODE CODE	2	<24-26>
90	BLANKING PERIOD CODE	2	<32-39>
91	INITIAL SIGNAL THRESHOLD CODE	2	<40-46>
92	BOTTOM DETECT S/N MARGIN CODE	2	<48-55>
93	SIGNAL THRESHOLD SLOPE CODE	2	<56-62>
94	SWITCH DEPTH CODE	2	<64-71>
95	PROFILE DELAY CODE	2	<73-79>
96	PEAK PULSE OFFSET CODE	2	<80-82>
97	PROFILE CYCLE TIME CODE	2	<88-90>
98-108	OTHER AMETEK PARAMETER CODES	22	
109	DOPPLER/AGC MODE CODE	2	<48-49>
110-113	UNDEDICATED	8	
114-116	SAIL MODULES ONLINE 1	6	< 00000- 65535>
117-119	SAIL MODULES ONLINE 2	6	< 00000- 65535>
120-128	SOFTWARE VERSION	18	<Vn.nn MO/DA/YR aut>

Appendix 10.2.1

Raw Data Record Header Format

WORD	DESCRIPTION	BYTES	RANGE
1-2	RECORD NUMBER	4	<0001-9999>
3-4	DAY OF YEAR	4	<0001-0366>
5	MONTH	2	<01-12>
6	DAY OF MONTH	2	<01-31>
7	YEAR	2	<84-89>
8	HOURL	2	<00-23>
9	MINUTES	2	<00-59>
10	SECONDS	2	<00-59>
11	HUNDREDTH SECONDS	2	<00-99>
12-13	LORAN 1 STATION REP RATE	4	<0000-9999>
14-17	LORAN 1 LATITUDE	8	< Nddmmxx>
18-21	LORAN 1 LONGITUDE	8	<Wdddmxx>
22-25	LORAN 1 TIME DELAY 1 (.1 us)	8	< 9999999>
26-29	LORAN 1 TIME DELAY 2	8	< 9999999>
30-33	LORAN 1 TIME DELAY 3	8	< 9999999>
34-37	LORAN 1 TIME DELAY 4	8	< 9999999>
38-39	LORAN 1 SIGNAL/NOISE 1	4	<Cxxx>
40-41	LORAN 1 SIGNAL/NOISE 2	4	<Cxxx>
42-43	LORAN 1 SIGNAL/NOISE 3	4	<Cxxx>
44-45	LORAN 1 SIGNAL/NOISE 4	4	<Cxxx>
46	SATNAV HOUR	2	<00-23>
47	SATNAV MINUTES	2	<00-59>
48	SATNAV SECONDS	2	<00-59>
49	SATNAV HUNDREDTHS	2	<00-99>
50-53	SATNAV LATITUDE	8	< N895999>
54-57	SATNAV LONGITUDE	8	<W1795999>
58	SATNAV ELEVATION	2	<90>
59	SATNAV SOLUTION ITERATIONS	2	< x>
60-62	SATNAV SPEED	6	< +nn.n>
63-65	SATNAV HEADING	6	< 359.9>

Appendix 10.2.1

Raw Data Record Header Format (continued)

WORD	DESCRIPTION	BYTES	RANGE
66-67	LORAN 2 STATION REP RATE	4	<0000-9999>
68-71	LORAN 2 LATITUDE	8	< Nddmmxx>
72-75	LORAN 2 LONGITUDE	8	<Wddmmxx>
76-79	LORAN 2 TIME DELAY 1 (.1 us)	8	<99999999>
80-83	LORAN 2 TIME DELAY 2	8	<99999999>
84-87	LORAN 2 TIME DELAY 3	8	<99999999>
88-91	LORAN 2 TIME DELAY 4	8	<99999999>
92-93	LORAN 2 SIGNAL/NOISE 1	4	<Cxxx>
94-95	LORAN 2 SIGNAL/NOISE 2	4	<Cxxx>
96-97	LORAN 2 SIGNAL/NOISE 3	4	<Cxxx>
98-99	LORAN 2 SIGNAL/NOISE 4	4	<Cxxx>
100	SATNAV DRT HOURS	2	<00-99>
101	SATNAV DRT MINUTES	2	<00-59>
102-128	UNDEDICATED	54	
129-131	AIR TEMPERATURE	6	
132-134	WET BULB TEMPERATURE	6	
135-137	WIND SPEED	6	
138-140	WIND DIRECTION	6	< 3599>
141-143	BAROMETRIC PRESSURE	6	
144-148	CONDUCTIVITY	10	<xxxx.xxxx>
149-153	TEMPERATURE	10	<xxxx.xxxx>
154-156	SURFACE TEMPERATURE	6	
157-159	SEA STATE	6	
160-162	SWELL DIRECTION	6	< 359.9>
163-165	SPEED LOG	6	
166-168	SHORT WAVE RADIATION	6	
169-174	WWV CLOCK	12	<DDD:HH:MM:SS>
175-178	GRAY HORSE RANGE 1	8	<99999999>
179-182	GRAY HORSE RANGE 2	8	<99999999>
183-251	UNDEDICATED	138	
252	SATNAV <FI>x or <DR>t mode	2	<FI-DR>
253	<FR>equency or <AM>plitude mode	2	<FR-AM>
254-256	STATION ID	6 *	<ANY CHRS>

Appendix 10.2.1

Raw Data Ping Header Format

WORD	DESCRIPTION	BYTES	RANGE
1-3	SHIP'S GYRO HEADING	6	< 359.9>
4-6	PLATFORM VERTICAL GYRO	6	< 359.9>
7-9	PLATFORM ROLL GYRO	6	< 359.9>
10-12	PLATFORM PITCH GYRO	6	< 359.9>
13-16	VERTICAL ACCELERATION	8	
17-20	ATHWARTSHIP ACCELERATION	8	
21-24	ALONGSHIP ACCELERATION	8	
25-27	MCTD CONDUCTIVITY FREQ	6	< NNNNN>
28-30	MCTD TEMPERATURE FREQ	6	< NNNNN>
31-33	MCTD PRESSURE FREQ	6	< NNNNN>
34-36	MCTD FLORIMETER	6	
37-39	MCTD BEAM TRANSMITTANCE	6	
40-42	TRISPONDER CHANNEL 1	6	<NNNNNN>
43-45	TRISPONDER CHANNEL 2	6	<NNNNNN>
46-48	TRISPONDER CHANNEL 3	6	<NNNNNN>
49-51	TRISPONDER CHANNEL 4	6	<NNNNNN>
52-61	UNDEDICATED	20	
62	PING MINUTES	2	<00-59>
63	PING SECONDS	2	<00-59>
64	PING HUNDREDTHS	2	<00-99>

Appendix 10.2.1

Raw Data Doppler Ping Data Block

WORD	DESCRIPTION		BYTES	RANGE
LSBYTE	1	PROFILER HEADER SYNC	1	<08>
MSBYTE	1	APOC SYSTEM ERROR FLAGS	1	<0-255>
	2	PROFILER SHIP'S HEADING	2	
	3	BOTTOM DATA	BEAM 1	BIN 0
	4	BOTTOM	BEAM 2	"
	5	BOTTOM	BEAM 3	"
	6	BOTTOM	BEAM 4	"
	7	PROFILE DATA	BEAM 1	BIN 1
	8	PROFILE	BEAM 2	"
	9	PROFILE	BEAM 3	"
	10	PROFILE	BEAM 4	"
	11-14	(AS ABOVE, BEAMS 1-4)	BIN 2	8
	15-18	(AS ABOVE)	BIN 3	8
	19-258	(AS ABOVE, BINS 4-63)		480
	259	PROFILER TRAILER SYNC BYTES	2	<465C>
	260	CATCH-ALL DATA WORD	2	??

Appendix 10.2.1

Raw Data File Format

This table shows the various data blocks in relation to each other.

WORD	DESCRIPTION	BYTES
1-128	FILE HEADER	256
	IRG (INTER-RECORD GAP)	
1-256	RECORD HEADER	512
257-320	PING 1 HEADER	128
321-580	PING 1 DOPPLER	520
581-644	PING 2 HEADER	128
645-904	PING 2 DOPPLER	520
905-1228	(AS ABOVE, PING 3)	648
1229-????	MORE PINGS	
	IRG (END OF RECORD)	
1-256	ANOTHER RECORD HEADER	
257-????	PINGS	
	IRG (END OF RECORD)	
	MORE RECORDS	
	IRG	
	FILE MARK (END OF FILE)	
	POSSIBLY MORE FILES	
	FILE MARK (END OF FILE)	
	FILE MARK (END OF TAPE)	

Appendix 10.2.1

Raw Data Error Flags

These flags are positioned in the ping data block, word 1, 2nd byte. A bit set means that during the previous ping, the error indicated was detected by the acquisition computer. Flags are reset after recording, so that if the error has been corrected, the bit will not be set in the next ping block.

BIT	WEIGHT	MEANING
0	1	AMETEK ERROR
1	2	SAIL ERROR
2	4	TAPE UNIT ERROR
3	8	REAL TIME SYSTEM ERROR
4	16	CLOCK ERROR
5	32	FUTURE
6	64	FUTURE
7	128	ACQUISITION SYSTEM OK

Appendix 10.2.2

10.2.2 Processed Data Format

Data files on processed tapes begin with a file header based on the tape header of the input time-series data tape.

Data files consist of a repeated series of records, beginning with three data header records which contain information related to the velocity data set which follows.

Processed Data File Header Format

WORD	DESCRIPTION
1	Month of start of data
2	Day of month of start of data
3-4	Year
5	Hour
6	Minute
7	Second
8-9	Input tape reel number
10-11	Track line number (usually 1)
12-13	Station # associated with file
14-17	Program version which created the file (i.e.AP830317)
18-19	Unused
20-26	Cruise/ship identifier
27-29	Transducer offset angle, degrees * 100
30-34	Doppler unit identifier
35-39	Data logger unit identifier
40	# of data header records in this data version
41-50	# of variables in each of the data header records
51	# of variables in the velocity records
52	# of bins processed in each data series

Appendix 10.2.2

Processed Data Record Format

DATA HEADER RECORD # 1

STARTING BYTE NUMBER	DESCRIPTION	FIELD FORMAT
2	Day of start of data in interval	I3
6	Hour of start of data in interval	I2
9	Minute of start of data	I2
12	Second	I2
18	Mean day of data in interval	I2
22	Mean hour	I2
25	Mean minute	I2
28	Mean second	I2
30	Input record number of first record in interval	I6
36	Number of records averaged in this data interval	I6
42	Number of pings averaged	I6

DATA HEADER RECORD # 2

2	Data flag, -999.99 for current version	F10.4
12	Average latitude, unsigned decimal degrees	F10.4
22	Average longitude, unsigned decimal degrees	F10.4
32	Ship's velocity north, averaged	F10.4
42	Ship's velocity east, averaged for this interval	F10.4
52	Averaged ship's heading, in degrees	F10.4
62	Average temperature of transducer (Celsius)	F10.4

Appendix 10.2.2

Processed Data Record Format (continued)

DATA HEADER RECORD # 3

2	Average sound velocity, from Seabird data	F10.4
12	Average surface temperature	F10.4
22	Average Seabird bath temperature	F10.4
32	Average conductivity of Seabird sensor	F10.4
42	Available for future use	3F10.4

VELOCITY RECORDS

2	Bin number	I3
7	Mean depth of bin, in meters	F8.3
17	Horizontal water velocity north, meters per sec	F8.3
27	Horizontal water velocity east, meters per sec	F8.3
37	Vertical velocity calculated from north velocity	F8.3
47	Vertical velocity from east velocity	F8.3
55	Number of pings averaged in this bin	I8

Appendix 10.2.3

10.2.3 Averaged Data Format

The file header for averaged data tapes is requested by the processing unit from the AU at program startup and whenever an operator directs the program to begin a new output file. This record is identical to the raw data file header, except that two fields have been added to assist with reading the tape. Word 15 is the number of raw records averaged, and words 16-18 represent the length of the data records, in bytes.

The averaged data file header is a 128 word (256 byte) record containing parameters and information which will remain constant for each data record in the file. The file creation date and time, tape reel number, acquisition software version, cruise/ship ID, and various acquisition system parameters are included in this record, as noted below. All data items in the file header are in ASCII format.

A file consists of this header, plus a number of data records. The processing program always writes a file header to tape at start-up, and optionally precedes it with an end-of-file to handle situations where the previous file was not terminated correctly.

Appendix 10.2.3

Averaged Data File Header Format

WORD	DESCRIPTION	BYTES	RANGE
1-2	DAY OF YEAR	4	<0001-0366>
3	MONTH	2	<01-12>
4	DAY OF MONTH	2	<01-31>
5-6	YEAR	4	<1984-1989>
7	HOUR	2	<00-23>
8	MINUTE	2	<00-59>
9	SECOND	2	<00-59>
10-11	TAPE REEL ID	4	<ANY CHRS>
12-13	TRACK ID	4	<ANY CHRS>
14	TAPE FILE ID	2	<00-99>
15	# OF INPUT RECORDS AVERAGED	2	<01-99 >
16-18	DATA RECORD LENGTH IN BYTES	6	<000001-32767>
19	UNDEDICATED	2	
20-29	CRUISE ID	20	<ANY CHRS>
30-34	DOPPLER ID (XXX=115 or 300)	10	<DCP4400XXX>
35-39	LOGGER ID	10	<ANY CHRS>
40-59	COMMENT LINE 1	40	<ANY CHRS>
60-79	COMMENT LINE 2	40	<ANY CHRS>
80-81	RECORD HEADER BYTE SIZE	4	<0256-8192>
82-83	PING HEADER BYTE SIZE	4	<0032-8192>
84-85	PING DATA BYTE SIZE	4	<0520-????>
86	PINGS PER RECORD	2	<01-99>
87	TRANSMIT PULSE WIDTH CODE	2	<08-14>
88	RANGE BIN SIZE CODE	2	<17-21>
89	PROFILER OPERATING MODE CODE	2	<24-26>
90	BLANKING PERIOD CODE	2	<32-39>
91	INITIAL SIGNAL THRESHOLD CODE	2	<40-46>
92	BOTTOM DETECT S/N MARGIN CODE	2	<48-55>
93	SIGNAL THRESHOLD SLOPE CODE	2	<56-62>
94	SWITCH DEPTH CODE	2	<64-71>
95	PROFILE DELAY CODE	2	<73-79>
96	PEAK PULSE OFFSET CODE	2	<80-82>
97	PROFILE CYCLE TIME CODE	2	<88-90>
98-108	OTHER AMETEK PARAMETER CODES	22	
109	DOPPLER/AGC MODE CODE	2	<48-49>
110-113	UNDEDICATED	8	
114-116	SAIL MODULES ONLINE 1	6	< 00000- 65535>
117-119	SAIL MODULES ONLINE 2	6	< 00000- 65535>
120-128	SOFTWARE VERSION	18	<Vn.nn MO/DA/YR aut>

Appendix 10.2.3

Averaged Data Record Format

BYTE	DESCRIPTION	FORMAT
2-7	START RECORD	I6
9-10	YEAR	I2
12-15	START DAY	I4
17-20	START HOUR, MINUTE	2I2
22-23	START SECONDS	I2
25-30	END RECORD	I6
32-35	END DAY	I4
37-40	END HOUR, MINUTE	2I2
42-43	END SECONDS	I2
82-91	LORAN 1 MEAN LAT	F10.4
93-102	LORAN 1 MEAN LONGITUDE	F10.4
104-113	LORAN 1 STATION REP RATE	F10.4
116-122	LORAN 1 S/N RATIO CHAIN 1	F7.2
124-130	LORAN 1 S/N RATIO CHAIN 2	F7.2
132-138	LORAN 1 S/N RATIO CHAIN 3	F7.2
140-146	LORAN 1 S/N RATIO CHAIN 4	F7.2
162-171	LORAN 2 MEAN LATITUDE	F10.4
173-182	LORAN 2 MEAN LONGITUDE	F10.4
184-193	LORAN 2 STATION REP RATE	F10.4
196-202	LORAN 2 S/N RATIO CHAIN 1	F7.2
204-210	LORAN 2 S/N RATIO CHAIN 2	F7.2
212-218	LORAN 2 S/N RATIO CHAIN 3	F7.2
220-226	LORAN 2 S/N RATIO CHAIN 4	F7.2
242-251	SATNAV MEAN LATITUDE	F10.4
253-262	SATNAV MEAN LONGITUDE	F10.4
264-273	MEAN SHIP'S VELOCITY NORTH (m/s)	F10.4
276-284	MEAN SHIP'S VELOCITY EAST (m/s)	F10.4
322-331	LAST SATNAV FIX LATITUDE	F10.4
333-342	LAST SATNAV FIX LONGITUDE	F10.4
344-347	HOURS SINCE LAST REPORTED FIX	I4
348-351	MINUTES SINCE LAST REPORTED FIX	I4

Appendix 10.2.3

Averaged Data Record Format (continued)

BYTE	DESCRIPTION	FORMAT
402-409	AVERAGE TRANSDUCER TEMPERATURE	F8.4
411-418	AVERAGE THERMOSALINOGRAPH TEMPERATURE	F8.4
420-427	AVERAGE CONDUCTIVITY	F8.4
429-435	SOUND VELOCITY USED IN WATER VECTOR CALCULATION	F7.2
482-488	MEAN WIND SPEED NORTH (m/s)	F7.3
490-496	MEAN WIND SPEED EAST (m/s)	F7.3
498-504	MEAN SHIP'S HEADING (degrees)	F7.3
562-568	TRANSDUCER OFFSET CALIBRATION FACTOR 1	F7.3
570-576	TRANSDUCER OFFSET CALIBRATION FACTOR 2	F7.3
578-584	TRANSDUCER OFFSET CALIBRATION FACTOR 3	F7.3
586-592	TRANSDUCER OFFSET CALIBRATION FACTOR 4	F7.3
594-600	TRANSDUCER OFFSET CALIBRATION FACTOR 5	F7.3
602-608	TRANSDUCER OFFSET CALIBRATION FACTOR 6	F7.3
610-616	TRANSDUCER OFFSET CALIBRATION FACTOR 7	F7.3
618-624	TRANSDUCER OFFSET CALIBRATION FACTOR 8	F7.3
626-634	TRANSDUCER OFFSET CALIBRATION FACTOR 9	F7.3
642-644	BIN NUMBER (BIN 1)	I3
646-653	BIN 1 DEPTH	F8.3
655-662	BIN 1 VELOCITY NORTH (m/s)	F8.3
664-671	BIN 1 VELOCITY EAST (m/s)	F8.3
673-680	BIN 1 VERTICAL VELOCITY (m/s)	F8.3
681-685	NUMBER OF PINGS IN AVERAGE FOR BIN 1	I5
722-724	BIN NUMBER (BIN 2)	I3
726-7645	as above for bins 2-63	
5682-5684	BIN NUMBER (BIN 64)	I3
5686-5693	BIN 64 DEPTH	F8.3
5695-5702	BIN 64 VELOCITY NORTH (m/s)	F8.3
5704-5711	BIN 64 VELOCITY EAST (m/s)	F8.3
5713-5720	BIN 64 VERTICAL VELOCITY (m/s)	F8.3
5721-5725	NUMBER OF PINGS IN AVERAGE FOR BIN 64	I5

Appendix 10.2.3

Averaged Data Record Format (continued)

BYTE	DESCRIPTION	FORMAT
5762-5770	LORAN(1) TIME DELAY RECORD 1 CHAIN 1	F9.3
5772-5780	LORAN(1) TIME DELAY RECORD 1 CHAIN 2	F9.3
5782-5790	LORAN(1) TIME DELAY RECORD 1 CHAIN 3	F9.3
5792-5800	LORAN(1) TIME DELAY RECORD 1 CHAIN 4	F9.3
5802-5810	LORAN(2) TIME DELAY RECORD 1 CHAIN 1	F9.3
5812-5820	LORAN(2) TIME DELAY RECORD 1 CHAIN 2	F9.3
5822-5830	LORAN(2) TIME DELAY RECORD 1 CHAIN 3	F9.3
5832-5840	LORAN(2) TIME DELAY RECORD 1 CHAIN 4	F9.3
5842-5850	LORAN(1) TIME DELAY RECORD 2 CHAIN 1	F9.3
5852-5860	LORAN(1) TIME DELAY RECORD 2 CHAIN 2	F9.3
5862-5870	LORAN(1) TIME DELAY RECORD 2 CHAIN 3	F9.3
5872-5880	LORAN(1) TIME DELAY RECORD 2 CHAIN 4	F9.3
5882-6880	as above for records 3-14	
6882-6890	LORAN(1) TIME DELAY RECORD 15 CHAIN 1	F9.3
6892-6900	LORAN(1) TIME DELAY RECORD 15 CHAIN 2	F9.3
6802-6910	LORAN(1) TIME DELAY RECORD 15 CHAIN 3	F9.3
6912-6920	LORAN(1) TIME DELAY RECORD 15 CHAIN 4	F9.3
6922-6930	LORAN(2) TIME DELAY RECORD 15 CHAIN 1	F9.3
6932-6940	LORAN(2) TIME DELAY RECORD 15 CHAIN 2	F9.3
6942-6950	LORAN(2) TIME DELAY RECORD 15 CHAIN 3	F9.3
6952-6960	LORAN(2) TIME DELAY RECORD 15 CHAIN 4	F9.3

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16. Abstract (Limit: 200 words) <p>An acoustic Doppler profiler has been designed into a multi-sensor Acoustic Profiler of Ocean Currents system (APOC). All four major components of this data collecting ensemble are micro-processor based units, allowing programmatic flexibility. Various water column, meteorological, and navigation data are recorded in a raw and/or processed form. Plots and listings of processed data are generated and displayed in real-time for use by investigators. Once installed, the system requires only a periodic change of cartridge recording media. The equipment has collected data during five cruises, for a total of approximately 190 days at sea. A hardware and software description of the system is presented. Preliminary technical results are discussed and evaluated.</p>			
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