DEVELOPMENT OF A NEW BOREHOLE ACOUSTIC TELEVIEWER FOR GEOTHERMAL APPLICATIONS

Troy K. Moore[1] Klemens Hinz[2] Jacobo Archuleta[3]

(1) Earth Science Instrumentation, Group ESS-6, Los Alamos National Laboratory, Los Alamos, NM 87545
(2) Westfalische Berggewerkschaftskasse, Institut fur Geophysik, Herner Strasse 45, 4630 Bochum, West Germany
(3) Mechanical Design Services, P.O. Box 364, Santa Cruz, NM 87567

ABSTRACT

Currently Westfalische Berggewerkschaftskasse (WBK) of West Germany and the Los Alamos National Laboratory of the United States are jointly developing a borehold acoustic televiewer for use in geothermal wellbores. The tool can be described as five subsystems working together to produce a borehold image. Each of the subsystems will be described.

INTRODUCTION

The tool described in this paper is an extension of the SABIS (Scanning Acoustic Borehole Image System) developed by WBK (Hinz and others, 1983). The new version not only will be temperature hardened for geothermal applications but will incorporate several new ideas (Dennis, 1985). General tool specifications are found in Fig. 1. The scope of this paper will be to describe in general the subsystems of the televiewer.

The borehole televiewer can be broken into five subsystems. The acoustic part transmits and receives each acoustic pulse used to map the borehole wall. The reflected signal is processed by the downhole electronics. Resulting data is PCM encoded and transmitted to the surface via a logging cable. Once the data arrives at the surface, the uphole control unit records the data on tape as well as provides the user with real-time outputs. Since the data will reside on tape, mission specific off-line processing procedures are easily applied.

In addition to mentioned design specifications, two other criterion have been addressed. The acoustic part of the tool has been placed as far forward on the tool as possible in order to provide a "look-down" prospective (Fig. 1). Also subassemblies have been modularly designed to aid in field assembly.

ACOUSTIC SUBASSEMBLY

The acoustic system houses two piezoelectric crystals mounted 180° apart on a rotating block. Either the 1.3-MHz or the 625-KHz crystals may be selected via the uphole control unit. The crystals are rotated in a silicon oil-filled cavity at 360 rpm by an ac synchronous motor.

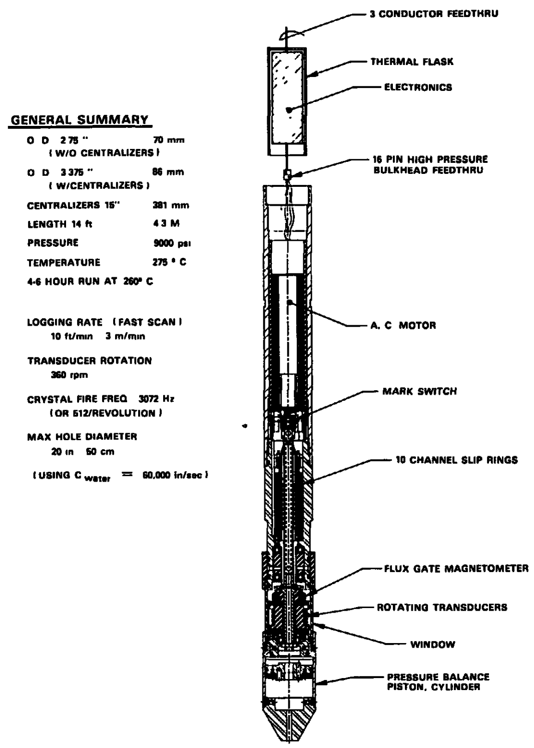

Figure 1. Borehole acoustic televiewer.

A Teflon window maintains separation between the silicon oil and borehole fluids. Pressure balance is preserved using a floating piston arrangement. Communication with the motor and transducer travels through a slip ring assembly and a high-pressure connector before reaching the downhole electronics.

DOWNHOLE ELECTRONICS

The downhole electronics subsystem is based around an Intel 8085 microprocessor responsible for control of the downhole data collection and transmission. Heat developed internally by the downhole electronics and heat from the environment are stored in a heat sink. The electronics and heat sink are packaged in a dewar for thermal protection.

For each shot the travel time of the first arrival and peak amplitude of the reflected signal are measured. To initiate a shot, the microprocessor triggers the selected crystal with a pulse. After ringdown, the crystal is reconfigured to act as a receiver of the reflected signal. At a predetermined time, the electronics begin listening for the return. The received signal is processed by an amplifier with an adjustable gain. The peak amplitude detected is retained. Both the time to begin the listening window and the amplifier gain are determined, based on previous shots, by the CPU.

Travel time of the first arrival is the time between firing the crystal and the reflected signal amplitude exceeding a threshold. The threshold is selected based on previous shots. To reduce noise in the received signal, the microprocessor synchronizes the signals driving the ac motor with receiver activities. This will guarantee that listening for a return and switching the motor current are mutually exclusive events.

Borehole temperature, temperature inside the dewar, and output from the three inclinometers represent data required only once per revolution. At specific times during a revolution, these conditions are sampled and available for encoding. A mark is generated to indicate a complete revolution of the acoustic part. Output from the fluxgate coil is interpreted to determine which shot most nearly aligns with magnetic north.

For uphole transmission, the peak amplitude and travel time values are appended together. Two additional bits are added to allow serial encoding of once per revolution parameters. The resulting data word is then PCM encoded.

LOGGING CABLE

The PCM encoded data is transmitted to the uphole control unit via 6600 m of 7-conductor or coaxial logging cable. Power for the downhole electronics is supplied using the logging cable.

UPHOLE CONTROL UNIT

The uphole control unit (Fig. 2) is constructed around the Siemens PMS-T 85D Microprocessor System (Intel 8085 CPU). This subsystem provides the user interface, controls the real-time outputs, and records the collected data on tape.

The uphole control unit provides the interface between the tool and the user. To

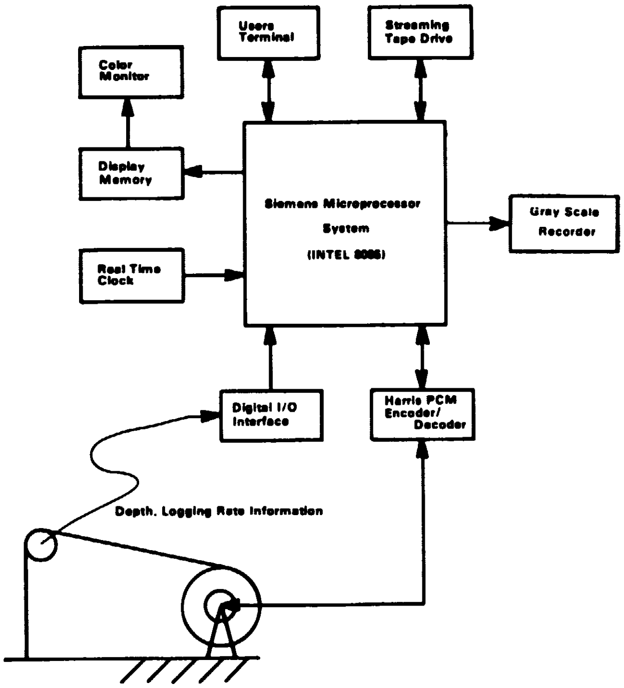

Figure 2. Uphole control system.

initiate and control tool operation, commands are entered at the system terminal. The format of the real-time outputs can be changed at any time. Once per revolution parameters displayed on the system terminal provides insight into the condition and operation of the tool.

Upon arrival at the surface, the data stream is decoded, the serial data is stripped off and placed in a parameter buffer. Travel time and peak amplitude values are separated and written to buffers. Date/time and logging rate values are input from external sources and included in the parameter buffer.

Data collected by the tool is displayed on a color monitor. A hardcopy may be generated by the gray scale recorder. Data is mapped to intensities via a user selected look-up table. Using mark and magnetic north information, data from a revolution is rotated to position the shot representing north as the first pixel in a raster scan line. Values from successive revolutions are inserted into the graphics controller such that the output of the color monitor will illustrate moving along the borehole.

Data is written to a 1/4-in. streaming tape on a revolution (mark-to-mark) basis. When all data from a revolution is present, the three buffers are written to tape as three records. A second set of buffers are present to allow concurrent I/O operations.

OFF-LINE PROCESSING

Real-time outputs may not provide sufficient information for an application. Off-line processing allows the user to manipulate collected data to meet specific needs.

The 1/4-in. tape provides a medium for transferring data to a minicomputer for further analysis. A first step may be to organize the data into a standard format prior to any additional processing. Operations involved may include: (1) data calibration, (2) rotating data using north information, (3) evaluation of borehole deviation, and (4) correction for tool not centered in borehole. Once initial processing has occurred, the data collection may be broken up into segments and placed in directories representing ranges of depths.

At this point, mission specific software may be applied. Such algorithms may include image enhancement, statistical analysis, pattern recognition, etc.

SUMMARY

A borehole acoustic televiewer is being developed jointly by West Germany and the United States. As the tool moves along the borehole, ultrasonic pulses are fired from a rotating head. The amplitude and travel time of the reflected pulse are measured by the downhole electronics and transmitted to the surface via the logging cable. The uphole control unit records the data and provides real-time output to the user.

REFERENCES

Hinz, K., and Schepers, R., SABIS (Scanning Acoustic Borehole Image System) -- The Digital Version of the Borehole Televiewer, Eighth SPWLA London Chapter Europe Formation Evaluation Symposium Transactions (1983).

Dennis, B. R., Private Communication to K. Hinz, Los Alamos National Laboratory (1985).