Courtesy Applied Automation, Inc.

Fig. 1—Observer talking to the recording truck from an OPSEIS Remote Telemetry Unit. These units are essentially four-channel, portable, digitizing boxes designed to relay seismic data without the use of wires.

A geophysical outlook—Part 2

Trends in multichannel seismic recording systems

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10-second summary

The trend towards more and more channels for seismic data collection is described in this article, the second in a series on new exploration technologies. The 1970s have led to the development of several new methods of simultaneously collecting seismic data with a large number of recording channels (up to 4,096) or seismic recording groups. This article addresses those multichannel geophysical recording systems that use telemetry data transmission methods, except for one that stores data on cassette cartridges.

IS BIGGER BETTER? Is a larger multichannel recording system going to help a company find more oil and gas and do it more economically? This question has to be answered by each exploration manager independently. Therefore, this article is aimed at providing a consolidated review of the frontier developments in multichannel geophysical recording systems in order to help explorationists become more completely aware of the available options.

There can be major problems when recording systems grow too big or too complex. How is it possible to keep track of where each of a large number of recording stations are located? What keeps the right geophone/hydrophone station tied to the proper recording channel? How are the surveying or positioning difficulties associated with many recording stations overcome? What improvements come as a result of putting more recording stations out simultaneously? Can the problems of increased size be minimized so that the system is cost effective, even without considering improved data results?

WHY MORE CHANNELS?

One of the most convincing reasons for larger numbers of active recording stations is that it is **less expensive to record the same amount of data.** The data collected with 1,000 recording positions covers more than ten times the surface area that a 96-channel crew does at each source position. A system with 384 channels will still provide four times the surface area or linear length coverage of a 96-channel crew per shot point or vibrator point. It does take longer to get 1,000 channels out on the ground than 96 channels, but with proper planning the movement of geophone stations along a line or over an area will go smoothly with either system. Monthly crew costs are estimated, on average, to be one-third more per month when one of the new, larger systems is operated, and this is still less expensive per amount of data collected. However, there are crew start up costs. One company had a start up cost budget increase from $2 million to $3.5 million when comparing starting a 96-channel crew and a new multichannel telemetry crew, respectively.

Data quality improvement is the second major factor favoring the new systems. More channels allow closer spacing of receiver stations, which helps preserve the continuity of reflection horizons, and accommodates longer spreads, which help distinguish between primary and multiple reflections[1]. There is improvement in the signal-to-noise ratio because of the increased redundancy fold that can be obtained. A better handle of critical weathering statics corrections is obtained with more geophone stations. The larger number of channels also allows access to and proper data collection in remote or inaccessible land prospects.

Expanding the number of channels allows for the extension of coverage to areas instead of lines. This improves the spatial sampling of 3D (three-dimensional) geological structures and provides a better picture of the subsurface. (Areal or 3D seismic data collection techniques are a separate topic that will be discussed in the next article in this series.)

A third argument for the new telemetry and cassette multichannel recording systems is that they **are environmentally sound.** In remote areas it is easier to run a long telemetry wire and set up a radio telemetry or cassette recorder than to cut a road for the doghouse (recording truck). These systems are designed to be used on completely portable crews. However, as with all environmental protection, the final decision is in the hands of man. It requires common sense on the part of the crew not to leave trash, start fires, tear up roads or otherwise damage the terrain.

DATA TRANSMISSION

Parallel systems. Present standard recording systems bring data from the seismic recording groups in parallel. In other words, there is a pair of wires from each geophone/hydrophone group that goes to a corresponding recording channel. These channels are the interface for putting the data on magnetic tape. For a standard land seismic crew, there are 96 channels in each cable coming into the doghouse. With a typical trace spacing of 220 to 440 feet per recording station and an average of 150 live stations on the ground, there are 6 to 12 miles of cable, with 96 pairs of wires, on the ground at one time. These wires are obviously subject to damage by any wildlife or vehicles.

Serial systems. In contrast to parallel, serial data transmission relays the data from a group of recording stations one at a time.[2] Serial data transmission is often referred to as telemetry transmission, because the data from the recording stations are sent to the recording unit as a string of data. This is the same process as a radio transmission, only the signal travels along a 2-strand wire similar to the wire to a TV antenna. Therefore, a wireline telemetry transmission of up to 1,024 recording stations would only have one pair of wires (as opposed to 96 pairs) connecting each recording station to the recording equipment. This allows for many more channels to be called with a smaller amount of wire out on the ground or in the marine cable. There is not even a need for wire connections to the recording unit if radio telemetry or cassette cartridges are used.

With the large number of channels that are being transmitted to the recording truck, there can be a significant time delay between each shot point. One radio telemetry system reports an average of 5 to 7 seconds total recording time for 4 channels. This means that if 1,000 channels were being recorded at once it would take between 20 and 30 minutes to get the data from one shot back to the recorder.

Another radio telemetry system estimates 10 seconds per channel, which means that for a 4,095-channel system it would take 11 hours to bring the data from one shot point back to the recording truck. This, of course, is not going to work in a field production environment.

MULTICHANNEL RECORDING

Marine systems. There are two major vendors of marine telemetry systems. These are Digicon, Inc.[3] and Litton Resources Systems, Inc.,[1,4,5] which is associated with Western Geophysical. It is not the purpose of this article to compare the different systems or to make recommendations as to which is the best to buy for any specific reason. Therefore, in writing about the capabilities of similar types of equipment of which the author is aware the discussion will not tie the equipment descriptions to a specific vendor.

The major component of telemetry digital streamer systems is the digitizing unit, which services 4 or 12 analog seismic hydrophone channels. One unit is described as being "incorporated into a neutrally-buoyant, corrosion-resistant titanium streamer section connector." These streamer digitization units are identical, or at the least have identical memory boards that can be easily interchanged for ease of maintenance. Instead of sending analog signals down several hundred pairs of wires to parallel banks of amplifiers, digitizers and recording instruments on the ship, the A/D (analog-to-digital) conversion is accomplished in the streamer digitizing units.

One unit has a time-division multiplexing system that puts digital data from 12 data channels and 2 auxiliary channels into a coaxial line. Each module receives its own separate control instructions from the operator using a control system based on signal propagation time in the cable. Crews with 192 and 480 channel cables are currently in operation. On these crews each channel is sampled at a rate of 1 ms (millisecond). The other system records 120 seismic channels at 1 ms sample rate, or 240 channels with a 2 ms sample rate. The streamer depth is precisely monitored with individually controlled units called birds, and the depth (± 1.5 ft. or 0.46 m) and bearing information (±0.35°) is recorded between shots.

One of the major reasons for developing these telemetry marine

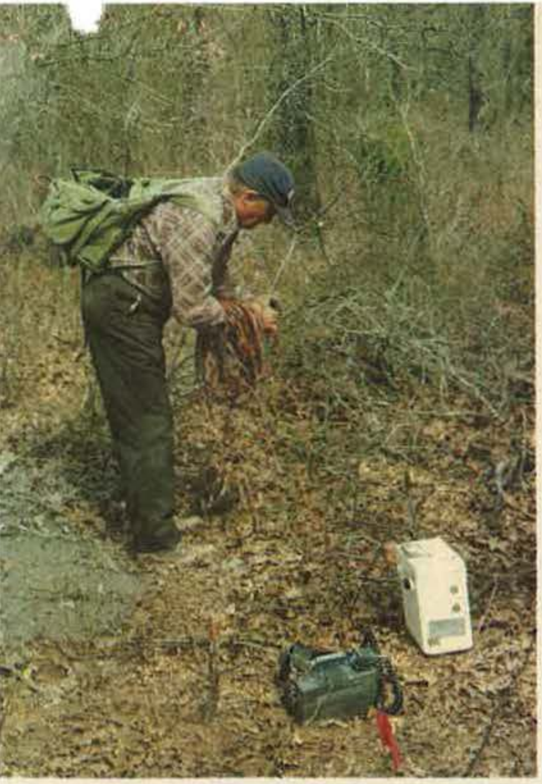

Fig. 2—An SGR cassette cartridge system being placed in the field. A single channel is recorded on the tape for every shot or vibrator point. Data from the individual tapes are dumped onto a larger system at day's end.

seismic systems is to meet the need for increased resolution in the horizontal direction (more traces per unit cable length) and in the vertical direction (recording higher frequency seismic information). Closer trace spacing increases horizontal resolution by making reflection horizons more continuous. There are variable section lengths between modules to aid in horizontal resolution.

Vertical resolution is improved as higher frequencies are recorded. One-eighth of the wavelength of the highest frequency recorded is the minimum bed thickness that can be resolved with a seismic reflection system.[6] Therefore the high-cut filter needs to be adjustable upwards to allow for the inclusion of higher frequencies, and the phase response of each hydrophone group has to be identical, so that combining them does not introduce frequency cancellation. The high-cut filter of one system can be telemetry selectable for frequencies 80, 160 or 320 Hz.

Land systems. Three types of land telemetry systems and a cassette cartridge system will be discussed in this section. The land serial recording equipment includes the wire line telemetry systems marketed by Gus Manufacturing and Sercel, the sign-bit GEOCOR IV wire line telemetry systems built by Geophysical Systems Corp., and the radio telemetry OPSEIS system marketed by Applied Automation, Inc. The system described as a surf zone system is built by Fairfield Industries. The SGR (Seismometer Group Recorder) cassette cartridge system is built and marketed by Gus Manufacturing.

Wire line telemetry systems that transmit 14 bits of data consist of remotely controlled boxes that collect, process, digitize, format and hold the data until the correct time slot for multiplexed transmission to the doghouse. In GUS-BUS terminology the Remote Data Acquisition Units are called RDAUs and the central recording unit a Line Interface Unit or an LIU.[7] Sercel calls the remote units Line Channel Boxes and the central unit a Sercel-SN 348.[8]

In one system the remote boxes have a clip that snaps around and breaks the twin-lead line insulation at any point one desires a station to be positioned. Thus any group interval or spacing is feasible. Each of these remote boxes serves four receiver stations.

The other system has single channel boxes that are separated in the field by 100 meters or less. A field power supply box boosts the signal between every set of 40 remote units. The systems have been developed to provide automatic self checking of unit status, and one system allows remote checking of geophone strings from the recording truck. A low frequency pilot tone precedes the shot to power up the remote units from standby. It takes 2 seconds for the entire line to settle down after powering up. The four channel units have a 4-digit indicator for ground station number, and units are called up by station number addresses for each data gathering cycle. After the data cycle ends, the unit returns to standby.

The units have remotely controlled low-cut and notch filters. When the author visited a GUS-BUS crew, data was being collected under a long distance power transmission line; no interference was noted on the monitors. If the line is inactive, a pocket-sized line communicator can be used to talk to the doghouse. The farthest unit can be 2 to 6 miles (3.2 to 9.7 km) from the recorder depending on environmental conditions. The four-channel remote units weigh 27 lbs. (10 kg), with batteries, and are 16 in. by 7.5 in. by 13 in. (40.6 by 19.1 by 33.0 cm) in size. The single channel box weighs only 3 lbs. (1.1 kg).

Because these systems use a simple two-wire cable, there are drastic reductions in cable costs. This makes it operationally feasible to deploy hundreds of channels in two dimensions. As many as fifty individual four-channel units may be connected to a single twin lead line, and the number of active units is limited only by the sample rate. Standard sample rates are 1, 2 or 4 ms. These systems can record up to 768 channels simultaneously. Typically 10 miles (16 km) of line (or 4, 10-mile lines) are used before moving the truck up. The one channel system can record up to 480 channels at a 4 ms sample rate. Some prospects, particularly 3D surveys over a known field, can be shot entirely from one setup. There are also automatic roll-a-long procedures for various line and areal data collection configurations.

Advertised accessories that are of interest include a 384-channel, solid-state compositor/demultiplexer that works with 16 second records that have a 1 ms sample rate "on the fly" (as fast as the data arrives at the box). Most vendors are building real time correlators and stackers that are compatible with their systems. One company advertises an 8,000 bpi (bit per inch) tape drive that can be added to compatible systems. Another sells 6,250-bpi tape drives for simultaneously recording a group of 480 channels. These drives do not have a vacuum column, which is very useful, especially where there is a lot of dust.

Sign-bit wire line telemetry is marketed as GEOCOR IV by Geophysical Systems Corp.[9] This system is able to simultaneously record and process 1,024 independent data channels at sample rates as small as ¼ ms. Data processing includes demultiplexing, correlating and compositing all of the channels as the data acquisition proceeds using a high speed processor with three million, 16-bit words of solid state memory. A 512-fold, CDP (common depth point) stacked section can also be generated off-line at the crew site nightly. These capabilities allow field tests to be evaluated and modified and recording param-

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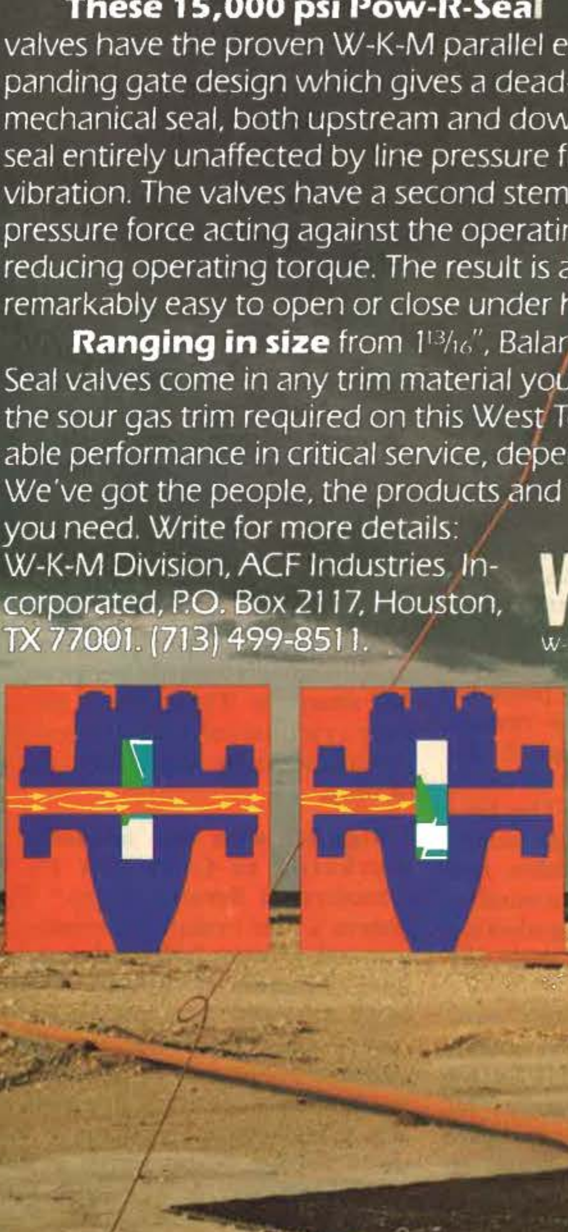

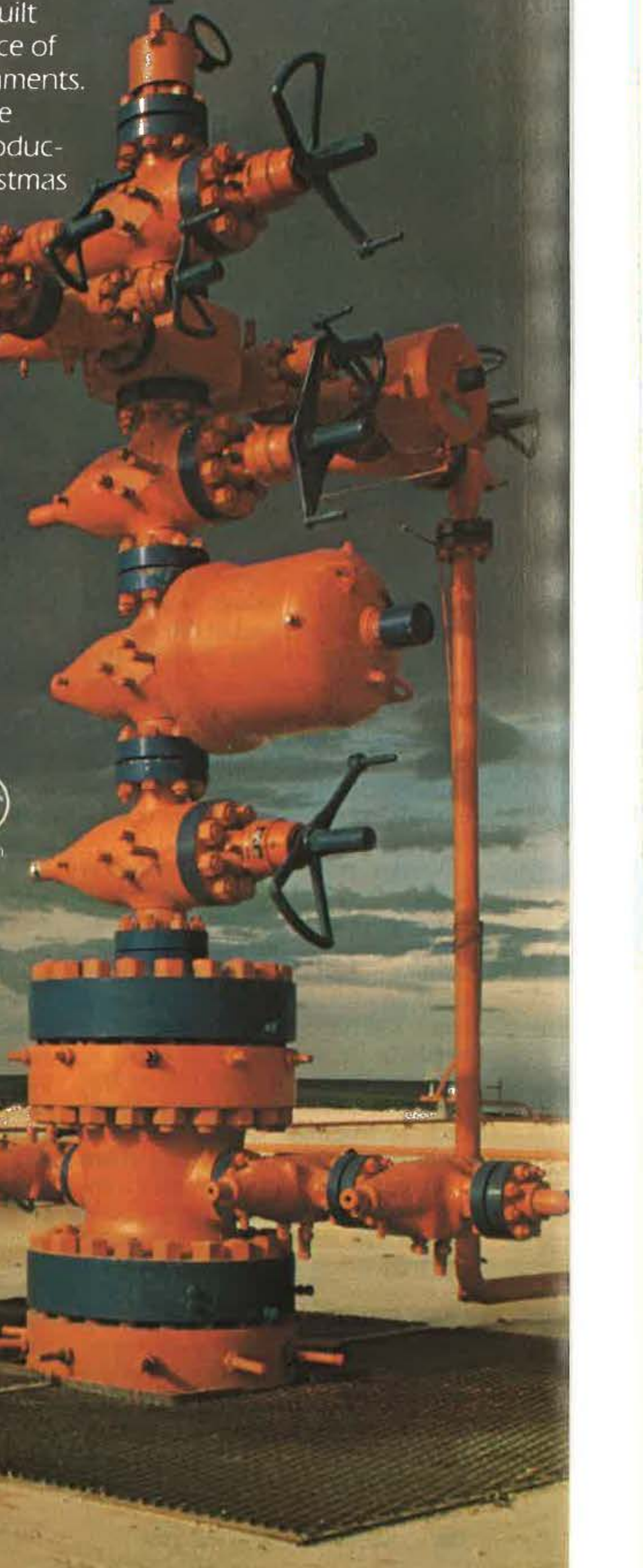

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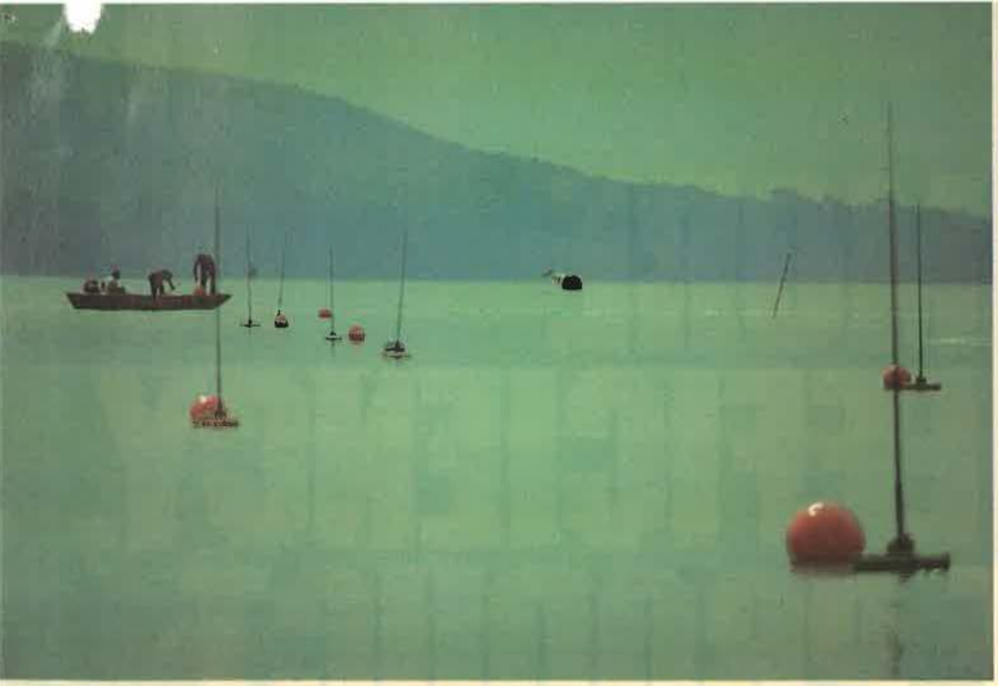

Fig. 3—A TELSEIS radio system at work in the field. Each channel utilized (up to a maximum of 66 channels) has a separate radio frequency. It can be operated from land or in shallow to deep water zones without equipment change.

eters to be regularly reset in the field to help improve data quality.

This system, like the wire line telemetry systems previously discussed, has a series of battery-operated boxes along the receiver spread. Each box controls the sampling and digitizing of data from 16 adjacent geophone channels. The data are transmitted to the recording truck in frames of serial data. Every frame is refreshed as it passes through successive terminals along the line so that the data can be transmitted long distances without being degraded.

The unique characteristic of the GEOCOR IV system is that only the polarity of the geophone signal is recorded. Positive polarities are noted with a 1 and negative polarities with a 0. Because the only numbers utilized are 0 and 1, and because this information can be recorded as one bit of data per time sample, the technique is called "sign-bit recording." It has been shown that accurate relative amplitudes can be recovered from the polarity information using correlation, compositing or high-fold CDP stacking. Synthetic tests at the Seismic Acoustics Laboratory (University of Houston) show that amplitude recovery of sign-bit data can be achieved by either stacking with a large fold (up to 480 was tested) or doing migration with a large enough aperture (100 traces were used).[10] The more traces that are added, the better the results. It has been argued that the need for higher fold and more spatially dense data requires that the same number of data bits be recorded as are recorded on a traditional 16-bit, 96-channel recording crew.

The data can be called from channels along a single line, or from up to 16 independent lines, as long as the total number of channels selected does not exceed 1,024. The recording truck can be placed at either end of a collection scheme or anywhere within the receiver stations to make the field operations more efficient. All operator communications take place through a CRT (cathode ray tube) with a standard keyboard using simple English. The system interrogates the operator for each parameter and checks the validity of each entry. This simplifies operation procedures and minimizes operator error.

Another capability of this system is the ability to vary the sweep frequencies between vibrator move-ups at the same shot point. High speed correlation before compositing makes this possible with no delay in data acquisition. GeoSystems calls this proprietary technique VARISWEEP. This allows the operator to tailor the frequency spectrum to emphasize the frequencies that best define the reflection sequences of interest.[9]

Radio telemetry systems are built and marketed by Applied Automation[11] and Fairfield Industries.[12] Fairfield is field testing a system similar to the Applied Automation OPSEIS. Telseis II can theoretically record 4,095 channels called in blocks of 12 or 24 channels. However, Fairfield systems are best known for surf zone seismic recording, and will be discussed under that heading.

The OPSEIS radio telemetry system (Fig. 1) is based on 4-channel digitizing boxes called Remote Telemetry Units (RTUs). Like the wire line telemetry systems, RTUs are portable units designed to work under the most adverse climatic and topographical conditions. They have an attachable flotation device so they can be used in swamps, lakes or other water environments. The RTU weighs 38 lbs. (17.3 kg) with the rechargable and removable battery pack and is 14 in. by 9 in. by 10 in. (35.6 by 22.9 by 25.4 cm). The batteries can be charged overnight from a single 115 volt AC plug. A telescoping directional antenna mounted to the case is used for both transmitting and receiving. A phone can be plugged into the RTU for communication to the doghouse when there is no data being transmitted.

The microprocessor that controls the RTUs has 254 discrete addresses, which allows 1,016 receiver channels to be recorded for each shot. The observer's CRT display has 200-channel page displays; therefore, the system is normally refered to as having 5 pages or 1,000 channels available. The recording channels can be assigned in up to 10 separate lines for 3D spreads. It takes an average of 5 to 7 seconds total recording time for 1 box or 4 channels to be transmitted to the recording unit. This time includes a 3 to 5 second overhead in the central recorder to demultiplex the four channels and print out a 64-channel camera paper record. Because the recording equipment is completely portable, a standard-sized recording truck seems very empty with just the OPSEIS recording equipment in it.

The data are transmitted exclusively over an RF (radio frequency) link between the remote locations and the central recording station. A repeatable command and data checking techniques insure data integrity even under poor signal conditions. The RF link is within assigned FCC (Federal Communications Commission) frequency bands. Seismic data are transmitted by paging through the RTUs over an 8 to 15 mile distance (depending on terrain). A repeater is presently being

field tested that will allow the recording unit to "see" over hills. The systems are also being expanded to enable real time correlation in the doghouse and to allow the stacking of vibrator move-ups in the RTUs.

The cassette cartridge recording system is called the Seismometer Group Recorder (SGR, Fig. 2), and is built and recently marketed by Gus Manufacturing. Each SGR has a single channel that is recorded on a cassette cartridge for every shot or vibrator point. Theoretically there is no limit to the number of channels that can be recorded using this system. In Wyoming, crews are being run with these systems that record 1,000 channels per shot point. The normal crew, doing non-3D data collection, will use 250 to 300 recording devices. Each tape holds little more than 160, six-second shot records on a standard 350-foot tape. There are 450-foot cassette cartridges available. The system is mostly used on shot crews, but it can be used with vibrators.

The cassettes are normally changed when the SGR is picked up as the line rolls along. When the box is located at the next station the location is noted with a dial on the box. The file number, record number, etc., are transmitted from the controlling point. The boxes are normally stored in 40 carrying racks on the back of a flat bed pickup. These racks have rechargers, for overnight recharging. Normally batteries are not replaced in the field, the dead unit is just replaced and recharged. At the end of the day the cassettes are dumped out onto 9-track, 1,600-bpi tapes at the crew office. This is done in a random order and the shots are put back in proper order in the home office as part of the preprocessing.

Surf zone systems. The OPSEIS system previously described can be used for surf zone recording. However, the most commonly used system is Fairfield Industry's TELSEIS 200 (Fig. 3).[12] It is set up so that each channel has a separate radio frequency. However, FCC regulations limit this to 66 channels in the U.S.; whereas, 96 channels are used overseas. This is different from the other telemetry systems that have been described because it records channels in parallel rather than serially. The system is designed to collect data in the "marine-to-land" gap. The telemetry units can be used continually as the spread progresses from land through swamp and surf zones and into the deeper waters. No equipment changes are required for these different environments and the system can broadcast to a maximum of 30 miles.

RECORDING SYSTEMS

It is safe to project that the standard manufacturers of seismic recording systems will continue to increase the number of channels and the resolution of their equipment. The active development of the 32-bit DFS-V is an example. This Texas Instruments' recording unit handles up to 240 channels with a sample rate that can range from 0.5 to 4 ms.

Another parallel recording system is Litton Resources Systems' LRS-9, which can record up to 960 channels at 0.5 ms sample interval. This is a modular system with 64 channels in each data acquisition module. Every pair of channels has "channelized" data storage so that recording on magnetic tape is independent of acquisition rates.[14] The development of real time correlators and compositors will have a major impact on the future production of standard parallel data acquisition systems.

New memory and electronics developments, in general, promise to further revolutionize acquisition systems. A list of some of the developments just over the horizon includes: all power coming from the truck and at lower level, full 132 decibel dynamic range with no gain ranging, telemetry units that only weigh a few ounces per trace, repeaters designed to build up a signal as it travels down the cable, fiber optics data transmission, laser light as a communication link instead of wire or radio telemetry, bubble memories tied to portable recording systems, video discs for very high-density field recording systems and satellite communication systems for telemetering data from an unlimited number of stations back to a central processing center. The future of reflection seismology multichannel acquisition systems is limited only by the imagination of today's explorationists.

About the author

H. ROICE NELSON, *Jr., received a B.S. degree in geophysics from the University of Utah in 1974 and an M.B.A. degree from Southern Methodist University in 1981. He was employed by Amoco Production Co. in the summers of 1970 and 1973. From 1974 to 1980 he held various geophysical positions with Mobil Exploration and Production Services, Inc., in Dallas, Texas. He became a senior researcher with the Seismic Acoustics Laboratory at the University of Houston in January 1980 and held that position until recently being appointed general manager of the Allied Geophysical Laboratories, associated with the same university. He is currently serving as a member of the SEG Research Committee.*

SUMMARY

The new developments in multichannel telemetry seismic systems are starting to have a major impact on the methods of exploration for petroleum energy. The multichannel systems range from wireline telemetry crews (marine and land) to radio telemetry systems (land and surf zone) to multiple, single-channel boxes that record data on cassette cartridges. Traditional parallel recording systems are rapidly increasing in the number of channels. They are also taking advantage of new electronic developments. There are many new technologies that need to be further developed and the future promises many more changes in data acquisition systems.

ACKNOWLEDGMENTS

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