analog magnetic tape under ideal conditions. The discrimination of distinct amplitude levels possible for an oscillograph record is equivalent to only 7 or 8 binary bits.

The dynamic range of analog tape recording systems is limited, under good operating conditions, to about 45 db for direct (AM) recording and about 60 db for frequency-modulated (FM) recording. Under ideal conditions, somewhat better values may be obtained; but it is doubtful if many systems reach even the cited values under field conditions. Ranges of 36 to 40 db for AM recording and 48 to 54 db for FM recording are more realistic.

In the case of AM recording, the overall limitation is set primarily by the tape media. The upper limit is the highest signal amplitude which can be recorded without distortion caused by magnetic saturation. The lower limit is the lowest amplitude which can be detected without distortion by background tape noise. In FM systems, the limits are set by the frequency-resolving power of the tape and equipment in combination. At low modulation frequencies, the signal output of the pickup heads is low, resulting in a tendency for the demodulators to drop out and free run. At high frequencies, the signal may not be resolved, and the same dropout condition occurs.

To increase the dynamic range of the analog amplifier, several methods of increasing the gain automatically as the seismic signal declines have been developed. The earliest and most common method, still, is the use of automatic gain control (AGC) circuits utilizing losser elements. With this method an analog gain-indicator signal, directly proportional to the amplifier gain over the period of the data run, is recorded on one of the channels of the analog tape. From this gain signal, the actual amplifier gain can be recovered on playback with an accuracy on the order of ± 5%.

The second method of increasing the amplifier gain-range is Programmed Gain Control (PGC). Gain is increased at specific times set in advance by the operator. With this method, the gain at each point on the record could, in theory, be known precisely. Unfortunately, in practice, the gain is recorded as an analog signal, still subject to a recovery of ±5%.

A combination of AGC and PGC has also been used. The early part of the record is handled with AGC; the latter part with PGC. The time of the changeover is selected by the operator, together with the time of further programmed-gain changes. This combination accomplishes smooth gain increases and has little adverse effect on the phase of the seismic signals. The drawback still persists, however, that the analog record of the gain is inaccurate. The operator must still be relied upon to predict accurately the behavior of the signal.

The best of the systems currently available combine AGC or PGC types of amplifier gain control with digital recording of the seismic traces, using 12 to 14 bits to record each sample. The recording resolution of these systems is, thus, in the neighborhood of 66 to 78 db. If the amplifier's static range is less than this digital capability, the precision of the digital recording is degraded to a corresponding degree. Furthermore, these combined systems are not able to recover amplitude any more accurately than the all-analog systems.

The main disadvantages of analog recording techniques, as compared with the possibilities of digital techniques, may be summarized as follows:

Limited dynamic range: Analog recording techniques have essentially reached a limit substantially short of digital recording.

Amplitude inaccuracy: This factor has been so poor that few companies have even attempted to analyze their seismic records by amplitude.

Poor time correlation: Comparison of the time relationships, trace to trace, can be no better than the accuracy of the analog tape recording. Inaccuracies are caused by variations of tape speed (wow and flutter) and track-to-track skew and can be overcome only partially by use of a timing reference track.