As a result, the output is not an exact amplified replica of the input. The distortion is present primarily as second and third harmonics of the principal input frequencies. For instance, the third harmonic of a 10-cps input signal would appear as a 30-cps output. With 1% harmonic distortion, the 30-cps output would have a magnitude of 1% of the 10-cps output. Thus, a severe 10-cps ground roll, 40 db above the amplitude of the reflection signals, would produce an erroneous 30-cps signal of the same amplitude as the reaction signals at 30-cps.

This example indicates how important it is that the seismic amplifier not introduce harmonic distortions which fall within the frequency range of the seismic signals. The frequencies which carry the information of greatest value in seismic work generally lie between 10 cps and 250 cps. To assure that this range of frequencies is passed without distortion through the pre-amplifiers, post-amplifiers, and buffer amplifier, the pre-amplifier was designed to have a passband of 5 to 2000 cps, and the overall response was designed to pass 5 to 1000 cps (down 3 db).

Two types of amplifiers could handle this range of frequencies: a-c amplifiers and chopper-stabilized d-c amplifiers. The last named was selected because the first has drawbacks in this application.

One difficulty in using an a-c amplifier in this application is that harmonic distortion increases at low frequencies. The general technique for reducing distortion is to increase amplifier feedback loop gain. If distortion through the amplifier were 100%--a worst-case assumption for design purposes--it could be reduced to 0.1% by designing loop gain to be 1000. Since distortion is probably much better than 100%, it is reduced to less than 0.1% by loop gain of 1000. To maintain this low level of distortion at low frequencies, such as 10 cps, loop gain has to be maintained down to d-c. In an a-c amplifier, however, loop gain declines at these low frequencies, resulting in increased distortion.

Furthermore, if an a-c signal is being passed through an amplifier and the gain is suddenly changed, a d-c component is introduced. The magnitude of this component depends on the point in the waveform at which the gain switching occurs. At the peak of a sine wave, for instance, this d-c offset equals one-half the integral of one-half cycle. In an a-c coupled amplifier, it decays at a rate determined by the time constant of the lower cutoff frequency of the amplifier.

The chopper-stabilized d-c amplifier avoids these difficulties because it can pass both d-c and a-c components. Consequently, loop gain can be maintained well over 1000 from d-c to beyond 1000 cps, reducing harmonic distortion to less than 0.1%.

The d-c component introduced by gain switching does not appear as a decaying error because of the presence of the d-c channel; but it is present as an offset. These offsets can be held to a fraction of a millivolt by careful design but, at higher gains, even this fraction becomes appreciable. In cascaded amplifiers, too, a small offset may be emphasized by succeeding amplifiers to become significant.

These errors are not large enough, generally, to be evident on an oscillograph record, since they are below the resolution of a galvanometer. In a high-resolution digital system, however, they become significant, and several design measures have been devised to overcome them.

First, the preamplifier is operated at a single fixed gain, x10. Any inaccuracies at this stage would be particularly important since the error would be amplified in the post-amplifiers and the buffer amplifier. By operating the preamplifier at a single gain, switching transients and d-c offsets are entirely avoided at this point.

Second, the gain of the two parallel post-amplifiers is always switched when the amplifier-being-switched is off line. Since these two amplifiers also operate at relatively low signal levels, followed by gain in the buffer amplifier, offset errors could be important. In order to be able to switch gain off line, these amplifiers are selectable. While one is carrying the signal at a