Experimental Evidence to Support the double Head Wave Method of Generating a Rare Faction First Motion

G. C. Werth

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In an earlier report, (Werth (1959)) a double headwave method of generating a rarefaction first motion was suggested. In this method a geologic situation is selected so that energy that has been critically refracted once above the shot and once below shot arrives first. Since the theory of headwaves gives in the usual stationary phase approximation a ninety degree phase shift for each critical refraction, energy that has been critically refracted twice produces a 180 degree phase shift. Oil well data was presented to show that the necessary geologic situation exists in nature.

A question has come up regarding the propagation of long wave lengths (16,000 ft) in the thin bed (3000 ft.) above the shot in the geologic situation cited in that report. At the time of writing of the report it was realized that the thickness of the bed should be considered in propagating the 3 to 5 wavelengths along the bed.

The theoretical problem of propagation in high speed elastic bed has not been solved. Probably the most advanced work is that of Terry Spencer (1959) at The California Research Corporation. The equations have been worked out and the programming for the computer nearly finished. Until that work is available all that can be argued theoretically is on a qualitative bases.

Rays which follow the refraction in the thin bed are internally reflected an odd number of times. For longitudinal waves, at least, there is a polarity reversal on each reflection and hence the tendency of these rays will be to force a further phase shift in the refraction, shifting it beyond 90 degrees. The relative amount of energy in the refraction and the internal reflection was not known at the writing of the report but it was felt that the internally reflected energy would not undo the phase shift of the refraction.

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Seismic model work by Riznichenko and Shamina (1957) has borne out this contention. It turns out that the internally reflected energy has higher amplitude, and the phase is shifted from the 90 degrees onto 180 degrees. His models (two dimensional) and seismograms are reproduced in figures 1, 2, 3, and 4. The positive break is shown in figure 4 for a thick layer as expected. In figures 2 and 3 for either the thin high velocity layer on a half space or for the embedded thin high velocity layer, a negative break is clearly evident.

These results say that the observed pulse would have, not the 180 degrees as given in the original paper, but more like a 270 degree-phase shift. Hence the internal reflections have not undone the phase of the refraction. Since 270 degrees is a rarefaction first arrival, the original conclusion still stands. We must realize that theory of propagation in high speed layers or even the detailed character of the refraction arrival itself is not fully known. This experimental work by Riznichenko and Shamina is suggestive of polarity modifications possible by refractions in thin and thick beds.

The best information available at this time indicates that it might indeed be possible to go out into reef country and experimentally find a location suitable to generate a rarefaction first motion by the double head wave method. As in the earlier report this scheme is offered only as a second method that could fool a set of rules regarding first motions.

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—Investigation models. The propagation velocities V and the length λ of the longitudinal waves observed are indicated.

Fig. 1

—Seismogram for a thin high-velocity layer lying underneath a lower-velocity layer.

Fig. 2

—Seismograms for a thin high-velocity layer surrounded by a lower-velocity medium.
 (a)—with great amplification; (b)—with small amplification.

Fig. 3

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