have been reported by several workers [e.g., *Chang and Barsch*, 1967, 1973; *Frisillo and Barsch*, 1972]. Bond phase shifts could be significant sources of error in such measurements. Some curvature is evident in Figures 6 and 7, even for f = 30 Mhz. In Figure 7 at f = 30 Mhz, the slope increases by about 20% over the 10 kbar pressure range. This would correspond to a change in $M' = \partial M/\partial P$ of about -0.01. Assuming a bulk modulus K = 2 Mbar then gives a change in KM'' of about -2. This is comparable to the accuracy claimed in some of the measurements referred to above. Of course, any deviation of f from f_{ro} could considerably increase this effect.

C. Other Measurement Procedures

Spetzler [1970] determined pressure derivatives by measuring the pressure dependence of the peaks and troughs in the interference pattern (Figure 3a), i.e. by measuring the derivative $(\partial f/\partial P)_\phi$ rather than $(\partial \phi/\partial P)_f$. (*Spetzler* used a buffer rod, but the same procedure might be used without a buffer rod.) The transducer-bond phase shifts in this case will depend on the difference between the transducer and sample derivatives, $\partial(f_s - f_r)/\partial P$. The expressions above can be generalized to allow for the variation of the carrier frequency f. For compressional waves, both derivatives will be positive and will tend to cancel, so that the bond phase shifts should be no greater than when f is constant. For shear waves, however, the sample derivative will most commonly be positive, while the transducer derivative is negative (for quartz), so that f_s may deviate considerably from f_r and the bond phase shift become significant. Also, *Spetzler* [1970] averaged measurements on a series of peaks and troughs near the transducer resonance frequency. If this was done without a buffer rod, significant bond phase shifts might affect those peaks and troughs not initially close to the transducer resonance frequency.

Another procedure that might be followed is to use the maximum amplitude response of the transducer to attempt to follow the resonance frequency of the transducer under pressure. However, when a transducer is bonded to a sample, the frequency at which maximum amplitude is obtained is not the free resonance frequency of the transducer, owing to the effect of the bond between the transducer and the sample. The expression for the response of the bonded transducer can be found in *Mason* [1958].

Figure 9 shows the relative amplitudes calculated for an X-cut quartz transducer bonded with V9 resin to a sample of olivine; curves are shown for several bond thicknesses ranging from 0 to 2 μm. The shift of the point of maximum amplitude to higher frequencies, owing to the presence of the bond, is apparent. The variation of the point of maximum amplitude with pressure is shown in Figure 10. The pressure dependence arises primarily from the change of the properties of the bond with pressure.

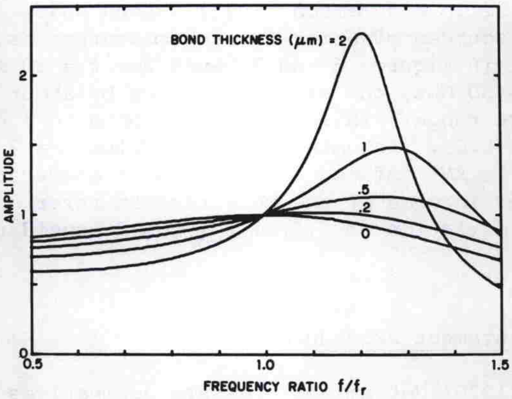

Fig. 9. Calculated relative amplitude versus frequency of X-cut quartz transducer bonded to olivine with various thicknesses of V9 resin.

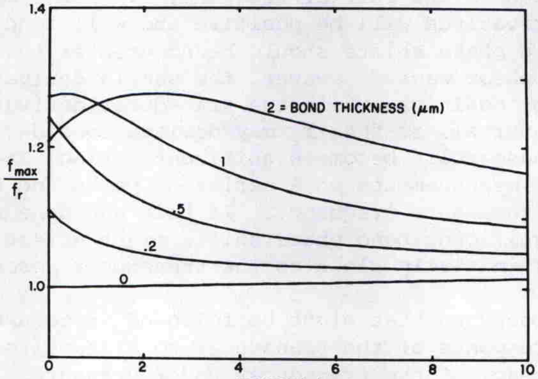

Fig. 10. Calculated frequencies of maximum amplitude in Figure 9 as a function of pressure.

If during an experiment the point of maximum amplitude was (wrongly) taken to be the resonant frequency of the transducer, then substantial errors could occur. It can be seen in Figure 4 that the phase shift due to the bond can be quite large, 1 or 2 Mhz above the free resonance frequency. Figure 11 shows the bond phase shift as a function of pressure when the operating frequency is kept at the point of maximum amplitude as shown in Figure 10. The phase shifts can easily be a large fraction of π, and vary significantly with pressure. A rough calculation shows that the