manual force is required to achieve a measurable signal), and presumably this contact is at a series of points scattered across the surfaces. The area of contact would be expected to vary with the normal force across the interface. A passing shear wave would not affect this force, but a compressional wave would. Thus, parts of the surfaces may be in contact, and thus transmitting the stress wave, only near peaks in a compressional wave; further, that part of the wave might be phase delayed because of the time required to bring the surfaces into contact, which might be a considerable fraction of the period of the wave. It is not at all clear at this stage that this kind of mechanism can explain the observations, but it serves to illustrate the possibility that the mechanical coupling at lapped contacts may be complicated and nonlinear. Partial wetting of the interface might produce additional effects, such as "squirting" of the liquid during compressional cycles, which could considerably modify the coupling. Presumably, complete wetting with even a weak couplant, such as isopentane, could eliminate or considerably reduce these effects. On the other hand, even the "dry" contact might be affected by condensation of vapor or by surface films in the interface. Although the surfaces were carefully cleaned with solvent before assembly, no extraordinary precautions were taken to keep them clean and dry. (Some measurements were made under modest vacuum, about 0.01 atm, with no observable effect. We also had to contend with curious colleagues, who wondered if we intended extrapolating to mantle pressures from measurements at 0 and 1 atm.) Until a better understanding of these phenomena is achieved, it seems clear that the results of measurements with buffer rods should be treated with some caution, especially in view of the large phase shifts observed with the dry or "wet" contacts.

These cautionary remarks also apply to measurements of pressure derivatives. It is premature to try to estimate the effect of pressure on the lapped contacts, except to note that, unless they are remarkably unaffected, they could be significant sources of error.

Spetzler et al. [1972] reported a large negative second pressure derivative of the bulk modulus of NaCl, which it is difficult to reconcile with shock compression data to 250 kbar [*Fritz et al.*, 1971], as was discussed by *Spetzler et al.* [1972]. They used a buffer rod, in dry lapped contact with the sample, and a gas (Ar) pressure medium. The quality of the contact may have been somewhat better than in the present experiments because the surfaces were polished flat to within 1/10 wavelength of light, NaCl is relatively soft, the surfaces were very carefully wrung together, and the contact area was only 5 mm in diameter [*Spetzler et al.* 1969a, 1969b, 1972; *Spetzler*, personal communication]. However, their measured zero-pressure velocities differ significantly from the extrapolation of the higher-pressure velocities to zero pressure. This may indicate some problem with the zero-pressure contact which was reduced as the Ar acoustic impedance increased at higher pressures.

Assuming that a bonded contact between the buffer and sample is "well behaved," as suggested above, the effect of pressure on the bond phase shift can be estimated. Bond properties similar to those in Table 3 were again assumed. Some results are illustrated in Figure 15 for compressional [100] waves in MgF_2, a fused quartz buffer, and several carrier frequencies and bond thicknesses.

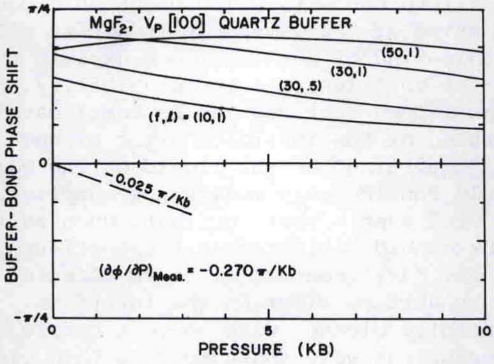

Fig. 15. Estimated effect of pressure on buffer-bond phase shifts for compressional [100] waves in MgF_2, fused quartz buffer rod, τ_f = 0.5 and 1 nsec and carrier frequency f = 10, 30, and 50 Mhz.

Again, the effective thickness of the bond decreases rapidly with increasing pressure. As mentioned earlier, this causes the position of the maximum phase shift to move to higher frequencies. Thus, in some cases, the phase shift first increases with increasing pressure, then decreases; in other cases, it decreases montonically. The magnitude of the effects are significant: for the curves in Figure 15, the slopes are up to 3° kbar. This could amount to 5% of the total phase shift; for the example in Figure 15, the measured phase shift was 49.2° kbar.

The buffer-bond phase shift can be reduced by having a thinner bond (as may be the case for the "immersed" contact discussed above), and by keeping the buffer to sample impedance ratio small. Values of Z_b/Z_s close to or greater than 1 allow phase shifts of up to 90°. (This may be another source of error in the measurements of *Spetzler et al.* [1972], since the relevant impedances of NaCl are probably all less than those of the fused quartz buffer rod used, although it is difficult to evaluate because of the uncertainty in the nature of the bonding.)

VII. CONCLUSIONS

No common source of errors in measurements of pressure