ablation surface and the shell thickness as a function of time for the worst unstable wavelength, $l=160$, for an initial amplitude of 14 Å rms. After passage of the first shock, the linear growth in time of the perturbation is evident. We have examined the $l=320$ mode and the growth rate and final amplitude were little changed. The suppression of growth rate seen here at short wavelengths is consistent with expectations for instability with a finite density gradient.[7]

Since the dispersion relation is flat around $l=160$ for this implosion, we have been able to run the $l=160$ mode throughout the implosion with 8 zones per wavelength. We find less than a factor of 2 change in calculated final amplitudes. In this implosion, no appreciable degradation of the thermonuclear yield is caused by fluid instability, either during ablative acceleration or in deceleration prior to burn, for an initial amplitude of 14 Å rms in the $l=160$ mode.

In a few test cases, we found that the effect of self-generated magnetic fields was negligible for surface-perturbed targets by use of the classical transport coefficients of Braginskii[8] or Bohm diffusion. However, since the fields reduce thermal conduction, they can significantly increase the surface perturbations imprinted by a given illumination nonuniformity. Techniques for creating a low-density corona to minimize effects of nonuniform illumination are under study.

We find no significant change in the fluid instability behavior when multigroup electron transport is included in the calculation.

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Knight Shift in Expanded Liquid Mercury

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We report the first magnetic data for an expanded liquid metal: the Knight shift in liquid Hg from the normal liquid density to less than 8 g/cm^3 at 1730 K and 1411 bar. An abrupt metal-nonmetal transition between 9 and 8 g/cm^3 is preceded by ranges of roughly linearly decreasing shift ($11 \lesssim \rho \lesssim 13.6$ g/cm^3) and constant shift ($9 \lesssim \rho \lesssim 11$ g/cm^3). The latter behavior fails to support current theories developed to explain electronic transport properties.

A simple band model of divalent metals predicts that if the density of atoms is reduced sufficiently, transformation to an insulating state should occur. The transformation results from narrowing and separation of the bands associated with the highest occupied atomic level and the first excited state. Because of its relatively low critical temperature and pressure, liquid Hg can be expanded to very low density by heating under pressure ($T_c=1760$ K, $P_c=1510$ bar). In this way Franck and Hensel first observed a continuous metal-nonmetal transition in the dc electrical conductivity of expanded fluid Hg.[1] Their work and subsequent investigations of the conductivity,[2,3] thermopower,[2,3] and Hall coefficient[4] show that Hg reaches a state of characteristically semiconducting behavior in the subcritical liquid at a density roughly 60% of that of the normal (room-temperature) liquid.

It has been generally supposed that splitting of the atomic 6*s* and 6*p* states evolves continuously from a "pseudogap" or minimum in the electronic density of states.[5] However, the nature of the states in the pseudogap and the mechanism of electronic transport near the metal-nonmetal transition have been the subjects of considerable recent interest and controversy. Conflicting models have been advanced by Mott[6] and by Cohen and Jortner[7] emphasizing, respectively, the roles of disorder-induced electronic localization and inhomogeneities due to density fluctuations.

In this Letter we report the first Knight-shift results for expanded liquid Hg. The measurements extend from the normal liquid metal through the metal-nonmetal transition. The data show an abrupt drop of the Knight shift near the density at which semiconducting transport properties first appear. On the metallic side of the transition, however, the observed density dependence of the shift appears to contradict fundamental assumptions of both the "localization" and "inhomogeneous" models.

Knight shifts were measured by use of a specially constructed internally heated autoclave consisting of a thick-walled BeCu cylinder closed with stainless-steel Bridgman seals. The pressure medium was argon gas. A noninductive heating element and the NMR sample coil were formed with Mo wire on Al_2O_3 ceramic forms. The high-temperature zone of the auotclave was insulated from the walls with alternating layers of highly porous ZrO_2 cloth and Mo foil, the latter serving to suppress convection within the cloth. With its thin external water-cooling jacket, the autoclave just fits into the 76-mm magnet gap.

The Hg samples were contained in a Lucalox cell connected by a stainless-steel capillary to an external reservoir maintained at the same pressure as the autoclave. A critical element in the success of the experiment was the use of a high-temperature Al_2O_3 glaze for sealing the sample cell.[8] Various configurations of Al_2O_3 forms were inserted into the cell in efforts to maximize the liquid-Hg surface area and thereby optimize penetration of radio-frequency fields into the metal. Good results were obtained with use of arrays of parallel sapphire fibers or a matrix of parallel 0.8-mm holes in a block of Al_2O_3 ceramic as well as with a simple bulk liquid sample.

Pressures were measured to ±1 bar with commercial Bourdon-type manometers. Our primary temperature determination was based on the vapor-pressure curve determined by Hensel and Franck.[9] At a given pressure, the vaporization temperature could be easily detected as a large change in the inductance of the NMR sample coil due to sudden reduction of the density of conducting material within. This procedure had the important advantage of sensitivity only to that portion of the sample contributing to the NMR signal. A W-Re thermocouple, external to the sample cell, was calibrated from the vapor pressure and, to minimize temperature errors, data were taken close to the liquid-gas coexistence curve.

The NMR of Hg^{199} was observed with conventional pulsed NMR techniques at a frequency of 13.2 MHz. Free-induction-decay signals were integrated with a boxcar integrator as the field was swept through resonance to obtain a symmetric absorptionlike profile.[10] The boxcar response was stored in a signal-averaging computer for repeated field sweeps. The weakness of the signals necessitated data accumulation periods of up to 4 h to achieve signal-to-noise ratios of about 4. Knight shifts ($\mathcal{K}$) were measured relative to the resonance position at 300 K and atmospheric pressure ($\mathcal{K}_0 = 2.72\%$).[11]

Experimental results for the Knight shift are presented in Table I with corresponding values of temperature (T) and pressure (P). Values of the density (ρ) for each set of P-T coordinates were obtained from the compilation given by Schmutzler.[12] When $\mathcal{K}$ is plotted as a function of ρ, as in Fig. 1, three distinct density ranges are apparent: For $\rho \gtrsim 11$ g/cm^3, $\mathcal{K}$ decreases in roughly linear fashion with decreasing ρ; in the range $9 \lesssim \rho \lesssim 11$ g/cm^3, $\mathcal{K}$ remains constant within ± 5%; finally there is an abrupt drop to nearly zero shift between 9 and 8 g/cm^3. The linear decrease of $\mathcal{K}$ above 11 g/cm^3, while not in accord with a free-electron-gas model, is nevertheless similar to observations for other polyvalent liquid metals (e.g., In)[13] during thermal expansion at atmospheric pressure. At the low-density end, the nearly vanishing shift below 8 g/cm^3 is consistent with the conductivity and thermopower which assume values typical of semiconductors at this density.

The surprising feature of the data is the range of nearly constant shift values observed between 9 and 11 g/cm^3. In this range the Hall coefficient rises by a factor of 3 above the free-electron value[4] and the conductivity drops by about one order of magnitude.[2,3] This behavior has been assumed[6,7] to characterize a regime of "strong scattering" or "diffusive" electronic transport where electrons in extended, metallike states

TABLE I. Experimental values for Hg^{199} Knight shift near the liquid-gas coexistence curve.

Point Number	P (bar)	T (K)	$\mathcal{K}$ (%)
0	1	300	2.72 ± 0.01[(a)]
1	34	501 ± 5	2.61 ± 0.05
2	93	675 ± 10	2.43 ± 0.05
3	39	738 ± 5	2.47 ± 0.05
4	44	882 ± 7	2.45 ± 0.05
5	42	901 ± 5	2.29 ± 0.05
6	43	935 ± 5	2.28 ± 0.05
7	45	955 ± 7	2.35 ± 0.05
8	104	1026 ± 5	2.19 ± 0.05
9	120	1090 ± 10	2.17 ± 0.05
10	204	1190 ± 10	2.10 ± 0.05
11	398	1300 ± 15	2.04 ± 0.05
12	649	1430 ± 15	2.10 ± 0.05
13	850	1490 ± 15	2.15 ± 0.05
14	999	1530 ± 20	2.10 ± 0.05
15	1203	1590 ± 20	2.08 ± 0.05
16	1005	1576 ± 15	2.01 ± 0.05
17	1223	1660 ± 15	1.98 ± 0.05
18	1268	1660 ± 15	1.39 ± 0.06
19	1279	1690 ± 15	1.12 ± 0.08
20	1404	1710 ± 15	0.64 ± 0.06
21	1411	1730 ± 15	0.13 ± 0.07

[a] Ref. 11.

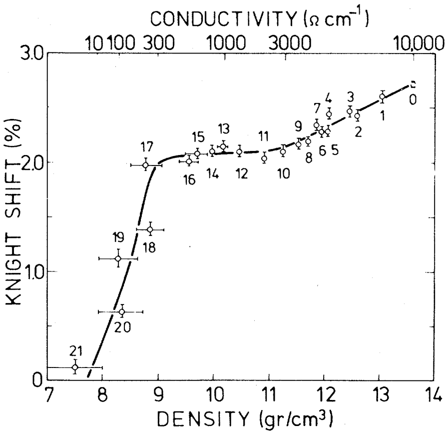

FIG. 1. Hg^{199} Knight shift versus density close to the coexistence curve in expanded liquid Hg. Densities (lower scale) were determined from Ref. 12. The variation of the dc conductivity (upper scale) represents data given in Refs. 1 and 2. Numbering of experimental points corresponds to Table I.

scatter with a mean free path equal to the interatomic spacing. The liquid structure in this regime is microscopically homogeneous in the sense that the characteristic length of density fluctuations is comparable with the mean interatomic spacing. Theories have been advanced by Mott[6] and Friedman[14] for the conductivity and Hall coefficient, respectively, in the homogeneous strong-scattering regime. When applied to liquid Hg, these theories require that the density of states at the Fermi level $N(E_F)$ drop by a factor of 3 between 11 and 9 g/cm^3. Now the dominant S-electron term in the Knight shift is proportional to the average probability amplitude of Fermi-surface electrons at the nucleus $\langle|\psi(0)|^2\rangle_{av}$ and the conduction-electron susceptibility χ_e. The latter is proportional to $N(E_F)$. Thus the constant observed shift can only be reconciled to the strong-scattering model if a decreasing $N(E_F)$ is just compensated by a corresponding rise in $\langle|\psi(0)|^2\rangle_{av}$ or an enhancement of χ_e.[15]

We are aware of no mechanism for such a large enhancement of χ_e in a divalent metal. An increase in $\langle|\psi(0)|^2\rangle_{av}$ towards the atomic value of $|\psi(0)|^2$ (typically a factor of roughly 2 greater than in the metal[16]) is an interesting possibility but is surprising should it occur on the metallic side of the metal-nonmetal transition. The value of $\langle|\psi(0)|^2\rangle_{av}$ would also increase if, as suggested by the work of Devillers and Ross,[17] there is a substantial increase in the fractional s character of states at the Fermi level. Compatible with this idea is Mott's proposal[6] that the s-band density of states varies much more slowly with energy near E_F than does the p band. A difficulty, serious but possibly not fatal for such an explanation, is that the fractional s character at high densities would have to be quite small. It would certainly have to be less than $\frac{1}{3}$ in order to compensate a threefold drop in $N(E_F)$. In such a case it becomes difficult to explain the large magnitude of $\mathcal{K}$ for $\rho \gtrsim 11$ g/cm^3 as well as the absence of a change in $\mathcal{K}$ due to a vanishing p-electron core-polarization shift in the range $9 \lesssim \rho \lesssim 11$ g/cm^3. Furthermore any such explanation has the obvious unsatisfying feature that it requires competing effects to just cancel so that $\mathcal{K}$ maintains a constant value over an appreciable range of densities.

We conclude therefore that current models centered on the strong-scattering description of electronic transport in the density range $9 \lesssim \rho \lesssim 11$ g/cm^3 are inadequate and, at best, require added sophistication to explain the local magnetic properties. Furthermore descriptions of the metal-nonmetal transition itself ($8 \lesssim \rho \lesssim 9$ g/cm^3) need reexamination since both the "localization"[6] and the "inhomogeneous"[7] models for this region take as a starting point the strong-scattering description for higher densities. There is an obvious need for an improved model of expanded liquid Hg which accounts for magnetic behavior as well as the usual dc electrical transport properties.

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