

setting at ± 5 kHz from the fundamental frequency. These two results were usually identical and did not differ by more than 0.1 pF. Having set the capacitance, the bridge resistance and generator frequency were varied until the balance was obtained. The bridge resistance was then set at twice the resonance value and capacitance and frequency were varied until the two half-conductance frequencies, indicated by f_1 and f_2 in fig. (5), were obtained. K_1 was calculated at each pressure from eqn (5) and this value was used in eqn (3) with the measured ΔR to calculate the viscosity of the liquid.

In fig. 5, the measured relationship between resistance, capacitance and frequency for a 39 kHz crystal immersed in benzene at atmospheric pressure and 25°C is shown. While capacitance does not enter the equations from which the viscosity of the surrounding medium is obtained, its significance is clearly indicated.

PURITY OF MATERIALS

All liquids investigated were obtained from Hopkin and Williams Ltd. Spectrosol carbon tetrachloride, and cyclohexane were used without further purification after checking the refractive index. R.I.-grade benzene was fractionally distilled over P_2O_5 and G.P.R. n- and iso-pentane were fractionally distilled over sodium wire.

RESULTS

VISCOSITIES

Table 2 gives the measured values of viscosity. The results are smoothed data from at least two runs with increasing and decreasing pressure, except for benzene at 40°C, cyclohexane at 34°C and carbon tetrachloride at 38.4°C for each of which only one set of measurements was made. The (pressure, density) data for the liquids were taken from Bridgman⁷ except for cyclohexane for which *PVT* measurements have been made by Holder and Whalley,⁸ and Reamer and Sage.⁹ Also shown in table 2 are the maximum pressures for each liquid and temperature. In fig. 6-10 the results in table 2 are compared with existing literature data.

DISCUSSION

The accuracy of the torsional crystal technique for measuring the viscosity of liquids at atmospheric pressure is indicated by the agreement between measured and calculated values of K_1 in table 1. An average agreement of 0.2 % was obtained with the worst agreement (0.5-0.6 %) occurring with the pentanes, for which there exists considerable uncertainty in literature values.^{4, 5} Our results are in keeping with the conclusion of the Franklin Institute report² that torsional crystal viscosity measurements in liquids are capable of an accuracy of 0.5 % or better.

In extending the use of this method for high pressures, additional sources of error were considered. These were (i) the inaccuracy of *PVT* data for liquids, (ii) contamination of the sample liquid by leakage of hydraulic fluid into the bellows assembly, and (iii) temperature variation in the oil bath or through heat of compression.

The probable accuracy of the density data is ± 0.1 % contributing an uncertainty of ± 0.2 % to the viscosity results. Since no differential pressure across the bellows seal occurred, seepage of hydraulic fluid was considered unlikely, and was not apparent in the results, where an increase in $(\partial\eta/\partial p)_T$ would result. As mentioned earlier, the bulk of the pressure vessel assisted in damping out temperature fluctuations in the bath. The elimination of temperature increases caused by compressions of the hydraulic and test fluids was monitored by the crystal resistance which clearly indicated when equilibrium had returned. The uncertainty in viscosity measurements under pressure was concluded to be approximately 1 %. Comparisons with existing

ESSURE
osity/cP

	50 1755
01	0.434
07	0.537
03	0.650
05	0.774
01	0.905
04	1.051
	1.211
	1.388

	50 1860
05	0.649
02	0.823
03	1.012
05	1.217
06	1.434
02	1.668
03	1.911
05	2.161

	50 870
00	0.605
07	0.675
02	0.751
02	0.833
01	0.923
	1.130
	1.374

	50 5200
	0.179
	0.275
	0.371
	0.470
	0.578
	0.848
	1.196
	1.646

	50 2100
	0.174
	0.279
	0.391
	0.510
	0.635