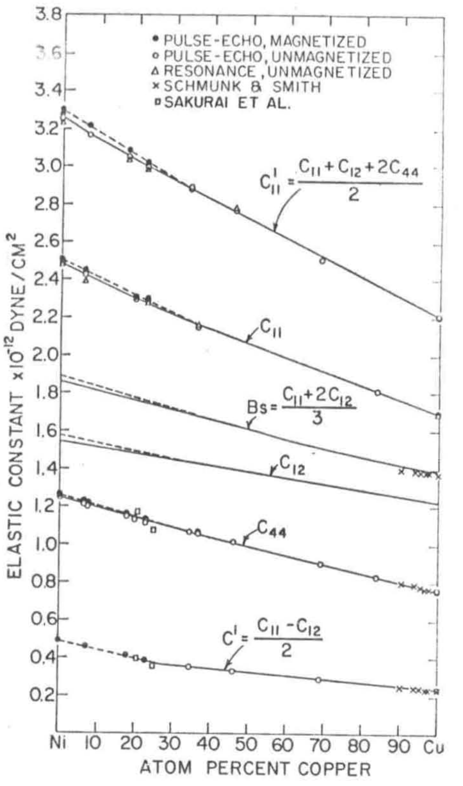

Fig. 2. The elastic constants of nickel–copper alloy single crystals in the magnetically saturated and unmagnetized states.

velocity determination in this case but in the magnetically saturated condition enough echoes were generated to permit an accurate determination (see column C of Table 2). No difference in the velocity or in the attenuation of the ultrasonic waves could be detected between measurements taken with the magnetic field parallel to the crystal axis and with the field perpendicular to the axis. The absence of any significant effects of field direction would be expected considering the low magnetostriction of nickel.

The data from Tables 1 and 2 are plotted in Fig. 2 showing graphically the relationship between the measured constants C_{11}, C_{44}, C' and C_L', and alloy composition. The C_{12} curve was derived from these data using the equation $C_{12} = 2C_L' - C_{11} - 2C_{44}$. The bulk modulus, B_s, was derived in a similar manner. The C_{12} constant was also determined from the relationship, $C_{12} = C_{11} - 2C'$ with good agreement being obtained in the two cases. The data of Schmunk and Smith[5] for the composition range of 0–10 at.% Ni were included in the construction of these curves as were the experimental points of Sakurai and co-workers.[14]

The dashed lines of Fig. 2 represent data for alloys in the magnetically saturated state. Although the increase in the elastic constants produced by application of the magnetic field is quite small, approaching the limit of experimental reliability in some cases, the difference is real and measurable. Repeated measurements made on individual specimens in the as-prepared condition, after magnetization and after annealing above the Curie temperature to demagnetize them gave reproducible evidence for this difference.

DISCUSSION

The elastic constants of pure copper obtained in this investigation are in good agreement with those reported by others and the elastic constants for both unmagnetized and magnetically saturated nickel single crystals also fall within the range of values reported in the literature. The addition of nickel to copper results in a linear increase in all of the elastic constants of copper over the composition range of 0 to 70 at.% Ni. The slopes of these lines can be expressed as the quantity $(1/C_0)(dC/dx)$ where C_0 is the corresponding constant for pure copper and dC/dx is the change in this constant with composition. This value for C_{44} is 0.61 and for C' is 0.74 as compared with Schmunk and Smith's values of 0.57 and 0.70 respectively which they obtained for dilute alloys of nickel in copper. Thus the linear relationship that Schmunk and Smith observed in the shear constants in the dilute solid solution range holds across most of the system. The unmagnetized alloys exhibit a slight deviation from this linearity in the ferromagnetic composition range for all but the derived C_{12} curve which is linear across the entire system.

These results support the conclusion of Sakurai *et al.* of a linear elastic constant versus composition curve for this system and a zero or slightly positive dissociation energy. Inasmuch as they found it necessary to apply a correction factor to the data of Shirakawa and Numakura, the results of the present investigation provide stronger supporting evidence for this conclusion.

The increase in all of the elastic constants of the ferromagnetic alloys of this system upon magnetization, referred to as the ΔE-effect, has been observed previously in other ferromagnetic materials. This has been attributed to the orientation of the domain walls by magnetization, although it should also be pointed out that a difference in the transit time correction between the magnetically ordered and disordered states could also produce this effect. The values that were obtained for C_{11} and C_{44} on pure nickel in the magnetically saturated condition were about 1 per cent greater than in the unmagnetized state. Bozorth *et al.*[8] and de Klerk and Musgrave[11]