DISCUSSION

C. E. Turner[1] (*written discussion*)—The author reports amongst other items the effect of specimen width on the Charpy V-notch transition temperature. It may be of interest to recall some previous work (Stone and Turner, *Proceedings*, Royal Society A, Vol. 285, 1965 pp. 83–103) in which width was varied by testing geometrically similar half-, standard-, and double-sized V-notch specimens, and also a large full plate 1-in.-thick specimen not geometrically similar. Tests were in slow bend, with similar scaled tests in notch tension and also the conventional Charpy V-notch impact test. The 50 percent fracture appearance transition temperature (FATT) showed a saturation with size similar to that reported by the author (Fig. 14). A summary of the 50 percent FATT for eight related

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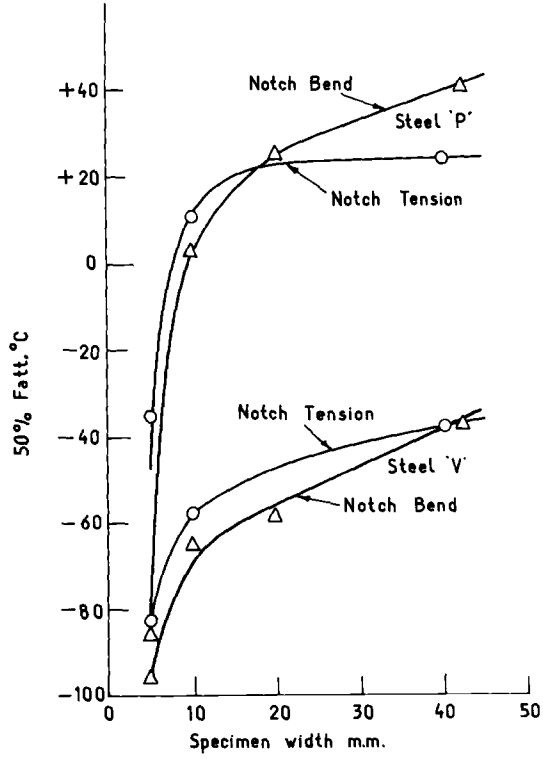

FIG. 14—*The effect of size on the transition temperature.*

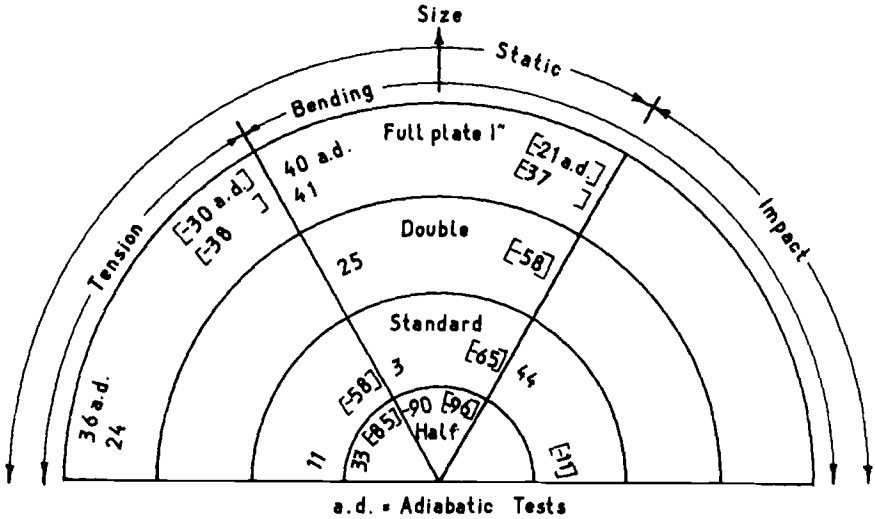

FIG. 15—*Fifty percent fracture appearance transition temperature, deg C, Steels P and V (Steel V in brackets).*

tests are shown (Fig. 15) for two mild steels. From such results and many others similar in trend, it surely is accepted generally now that for a given mild steel, size, temperature strain rate, and "damage" (such as pressed notches or strain aged material as a crack starter) can be traded off to get empirical co-relations between service behavior and a given test. As is also well known, these co-relations vary with the steel, test, and criterion of comparison and so are indeed very empirical.

It is also of interest to note that lateral expansion is proposed as a measure of transition. Expansion is a measure of compressive plastic flow under the striker and seems inherently the wrong measure for onset of tensile cleavage, except in the sense of a self-indicating load cell for each test. In the slow bend tests just mentioned, it was found that expansion agreed qualitatively with notch root contraction (NRC) which is, of course, a direct measure, albeit not always easy to make, of notch ductility. Recent work in England by the Navy Department Advisory Committee on Structural Steel (NDACSS) (presented at the Culcheth Symposium on Fracture Toughness Testing, April 1969) shows that NRC (absolute, not percentage) agrees well with crack opening displacement which is itself a logical measure of ductility transition. If therefore a more directly meaningful term than FATT is desired NRC has much to commend it. What is less clear, is whether tests should be on small specimens at high strain rate or full thickness at realistic strain rate. For COD and NRC values to be quantitatively meaningful, the NDACSS work shows full thickness to be essential. High strain rate is necessary only if (1)

dynamic action by loading or arrest of propagating cracks is in question and (2) if strain rate is to be used empirically to allow tests to be conducted with small sections. This latter should be restricted to purposes of quality control, since, as already seen, strain rate and size have no fundamental one to one relation for all steels, temperatures, or purposes.

J. H. Gross (author's closure)—The author appreciates Professor Turner's very pertinent comments. His confirmation that the thickness effect "saturates" at some level agrees with the results of a limited number of similar investigations. However, as pointed out in the paper, the thickness at which saturation occurs probably changes with the overall geometry of the specimen.

The author agrees that lateral contraction is theoretically a more desirable measure of notch ductility than lateral expansion. However, as Professor Turner confirmed, lateral expansion correlates so well with lateral contraction that the much greater ease of measuring lateral expansion indicates that it is by far the more practical method of measuring notch ductility in a Charpy V-notch specimen.

The author is most interested in the comment that recent work showed that the absolute rather than the percentage lateral contraction (or therefore lateral expansion) correlates with the crack-opening displacement. This observation suggests that the lateral expansion need not increase with thickness to ensure a constant notch ductility. As noted in the paper, studies on specimens significantly larger than double width are in progress to investigate this observation. Over the range of thicknesses studied previously (quarter width to double width), a lateral expansion of 15 mils would appear adequate to ensure some measure of through-thickness yielding. However, for very thick plates, for example 12 in., a lateral contraction or expansion of 15 mils may not be adequate to ensure significant through-thickness yielding, and failure would be expected to occur essentially by plane strain.

Professor Turner's concern for testing small specimens at high strains versus large specimens at "realistic" strain rates is believed to be important at this time only in the research area. In its present state of development, fracture mechanics cannot be used quantitatively to predict stress/flaw-size relations for structural steels with yield strengths lower than about 150 ksi, unless very large specimens are used or the tests are conducted at low temperatures or very high strain rates. Consequently, service performance can be predicted only by comparing the notch ductility of one steel with that of a steel of known service performance. In such qualitative comparisons, differences in strain-rate sensitivity are not likely to change the results of the comparison.