Fig. 4.12 Photograph of a commercial oscillating disk type curemeter. (*Courtesy Monsanto Company*)

following values be taken from the curve:

M_L = Minimum torque

M_{HF} = Equilibrium torque

M_{HR} = Maximum torque obtained for curve which exhibits reversion

M_H = highest torque value attained where no constant or maximum value is obtained

t_{sx} = scorch time to x units of torque increase above minimum torque

$t_{c(x)}$ = cure time to (x) percent of maximum torque development.

Figure 4.13 shows the three different types of cure curves which can be obtained with different types of rubber compounds. For example, some synthetic rubber compounds attain a constant or equilibrium torque level (M_{HF}) while most natural rubber compounds exhibit reversion (M_{HR}). The rubber technologist normally strives to develop a compound which neither reverts nor increases in modulus (torque) with overcure. Thus by using the above nomenclature recommended in the

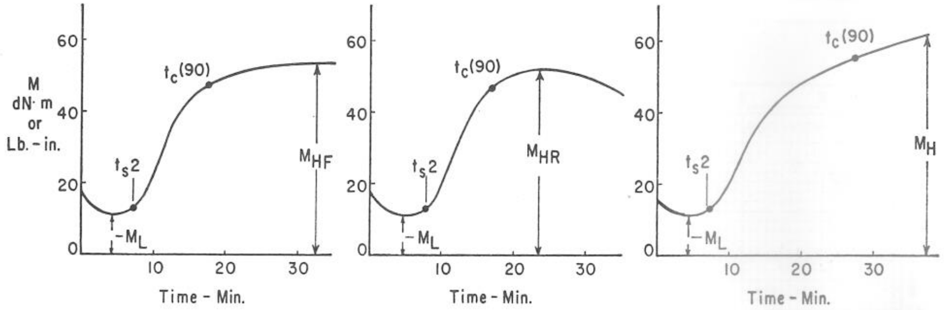

Fig. 4.13 Type of cure curves. Left curve: Cure to equilibrium torque. Middle curve: Cure to a maximum torque with reversion. Right curve: Cure to no equilibrium or maximum torque. (Source: ASTM D2705–68-T, Fig. 2, p. 38.)

ASTM method, the type of cure curve as well as all the other vulcanization characteristics of the compound is defined.

Uses of Curemeters The effects of compound variations on curing characteristics are important in compound development studies or production control. Curemeter tests are ideally suited for use in both these areas. In compound development, the composition of the compound can be varied until the desired vulcanization characteristics are obtained. The effect of compound changes on viscosity and scorch can be determined from the early portion of the cure curve, while from the latter portion, the effect on rate of vulcanization and the modulus of the cured compound can be measured. Figure 4.14 shows how relatively minor changes in the concentration of a compounding ingredient can be detected, and illustrates the immense value of curemeters in this area. The cure curve obtained with a curemeter is a "fingerprint" of the compound's vulcanization and processing character.

The ability of a curemeter to detect minor changes in the composition of the rubber compound has made it a widely accepted production control test. Another advantage is that the test can be run very rapidly. For example, by operating at test temperatures in the 350 to 400°F range, a test can be completed in approximately five minutes, which coincides closely with a typical Banbury mixing cycle. The procedure usually followed is to establish specification limits at several points along the cure curve as shown in Fig. 4.15. A cure curve is obtained on each batch of production stock prior to its use in fabricating the final product. Batches that yield cure curves which fall outside these acceptance limits are rejected.

Limits of acceptability for quality control purposes using a curemeter are normally set by running 30–40 consecutive batches of a compound on a single chart. This gives a representative "picture" of the batch-to-batch variation occurring. By correlating this information with experience, it is possible to set up limits of acceptability. By introducing deliberate variations in the mix in the laboratory and comparing the resulting rate curves, reasons for batch rejection can be determined.