The remaining lines to the left of the graph give the scales for the plotted variables. The scales are divided into four equal parts by the compiler. Scientific notation is used and the power of ten employed as a scaling factor is indicated either with a standard exponential designation, for example 5 E+10 or with an alphabetic character (see Figure E-2). For example, the scale for IC, plotted as C in Figure E-1, has an upper value of 40.R, which is $40 \times 10^{12}$ units. In the model run shown in Figure E-1, both the nonrenewable resource fraction remaining NRFR (plot symbol N) and the fraction of capital allocated to obtaining resources FCAOR (plot symbol F) are plotted on the same scale.

| Letter | Multiply Plotted Value by | Letter | Multiply Plotted Value by |
|---|---|---|---|
| A | $10^{-3}$ | N | $10^{30}$ |
| B | $10^{9}$ | P | $10^{24}$ |
| C | $10^{27}$ | Q | $10^{15}$ |
| D | $10^{33}$ | R | $10^{12}$ |
| E | $10^{-6}$ | S | $10^{21}$ |
| F | $10^{-9}$ | T | $10^{3}$ |
| G | $10^{-12}$ | U | $10^{-24}$ |
| H | $10^{-15}$ | V | $10^{18}$ |
| J | $10^{-18}$ | W | $10^{-27}$ |
| K | $<10^{-30}$ (off scale) | X | 1 |
| L | $10^{-21}$ | Y | $10^{-30}$ |
| M | $10^{6}$ | Z | $>10^{33}$ (off scale) |

**Figure E-2** Scaling letters used in DYNAMO

Time is plotted along the horizontal axis of the graph. The compiler attaches a "date" to the scale at every tenth plot period.

The series of letter groups that sometimes appear along the top of the graphical output indicate points at which two or more plot symbols overlap. The first letter is the one that is actually plotted in the output. The other letters identify the other variables whose plotted values intersect at that point. The intersections are purely geometric features of a given set of curves and scales; they are of no dynamic significance.

# Appendix F: Delays

The concept and characteristics of delays are important in understanding the dynamics of social systems. Complex social systems do not respond immediately and completely to changing conditions and inputs. One hundred letters mailed in the same mailbox to equidistant points will not arrive at their destinations simultaneously; the full effect of an advance in medical technology will not be reflected immediately in the average life expectancy of the population; an increasing number of births will be followed only many years later by an increasing number of deaths—all these illustrations are examples of delays.

In system dynamics models, a delay is represented by a combination of rates and levels. These combinations may be explicit: in the industrial sector the industrial capital depreciation rate ICDR (equation 53) is a delayed version of the capital investment rate ICIR (equation 55). The intervening level is the industrial capital stock IC (equation 52). The combination of rates and levels in a delay may also be implicit, as in the persistent pollution appearance rate PPAPR. The implicit combinations, denoted by SMOOTH and DELAY3, for example, are macro functions that are available in DYNAMO.

Delays have two dynamically significant characteristics. First, a delay postpones to a later time the full effect of a change in the input to the delay. The average displacement in time is determined by the delay "time constant," which may be either a constant or a variable during the run. Second, a delay modifies the time shape of an input. For example, a sudden increase in the input to a delay will be followed by a more gradual increase in the delay output.

## Information Delays

The information delays available in DYNAMO involve a smoothing, or averaging, of information about a variable, where the greatest weight is given to the most recent value of the variable and proportionately less weight is given to older information about the variable. This averaging procedure is often used to represent an intuitive averaging process in which the freshest, most recent events influence decisions more than the hazy recollections of past events. Dynamically, the smoothing