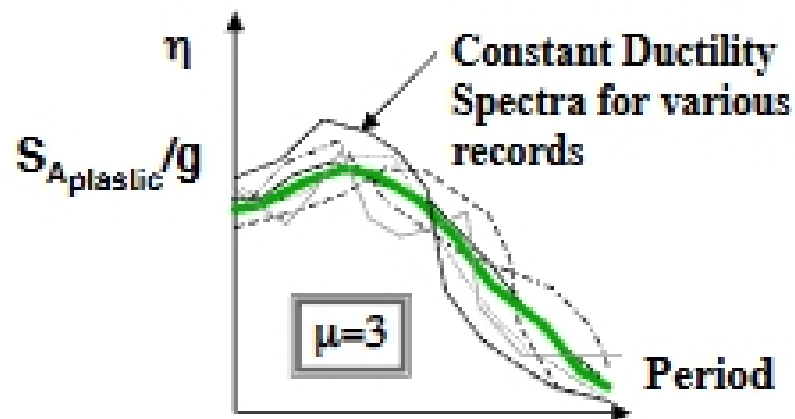
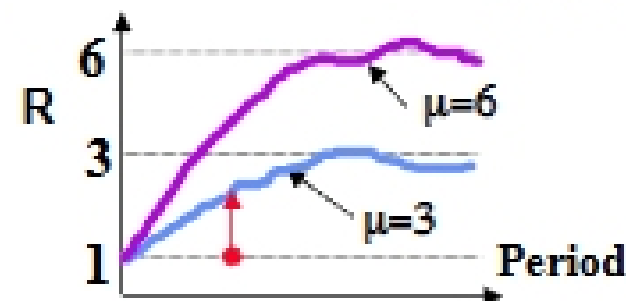
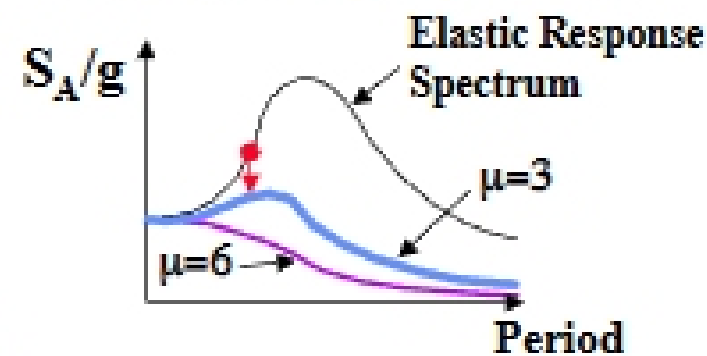


Inelastic Design Response Spectra

- Developed by statistical processing of actual nonlinear spectra for ground motions, hysteretic characteristics, ξ and damage indices of interest.



- Developed by modification of an elastic design spectrum.



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Scope of Discussions

Prefer:

- Actual spectra when site specific motions used.
- Empirical modification factors R and γ when elastic response spectrum specified.

→ Look at typical empirical modification methods for ideal EPP systems

- Newmark and Hall (et al)
- Multi-linear relations (Hidalgo, Riddell, ATC-32)
- Continuous functions (Miranda, Krawinkler, et al)

- **Next Section:** Examine briefly effect of and modifications for:

- $P-\Delta$ effects
- Shape of hysteretic loops
- Special ground motion characteristics
 - soft soils
 - near fault motions
- Viscous damping
- Duration of shaking other damage indices

- **Compare to code provisions**

- **Then:** Extend to multiple degree of freedom systems

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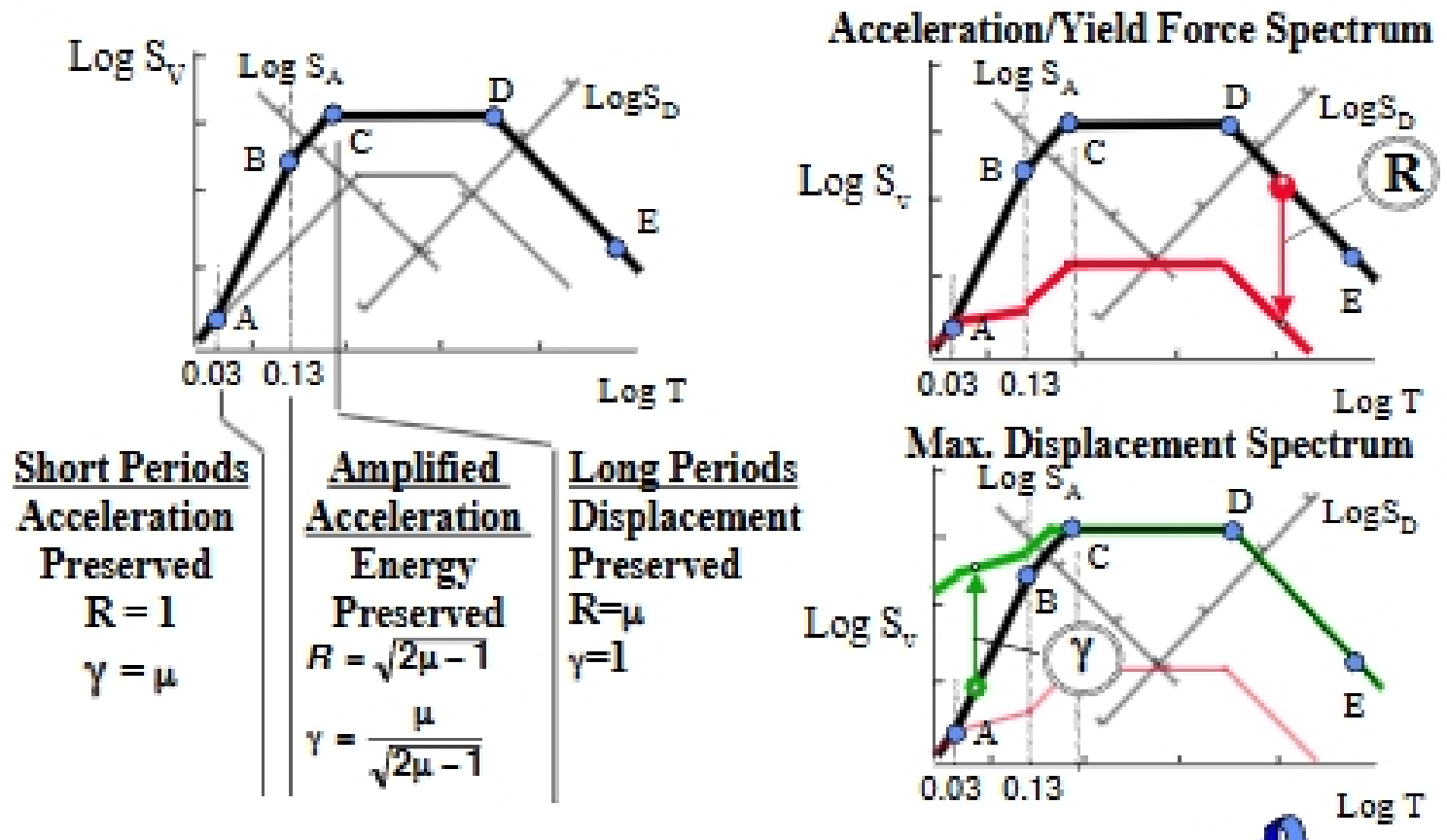
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Newmark and Hall IDRS Method



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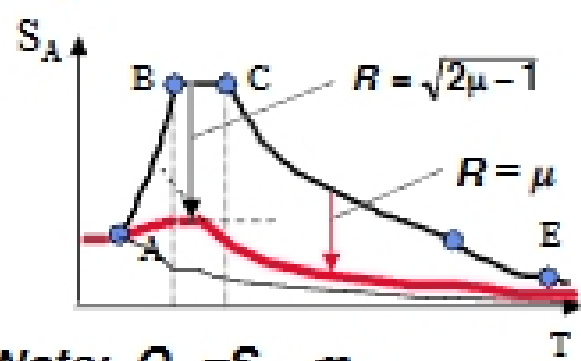
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Newmark and Hall IDRS (Continued)

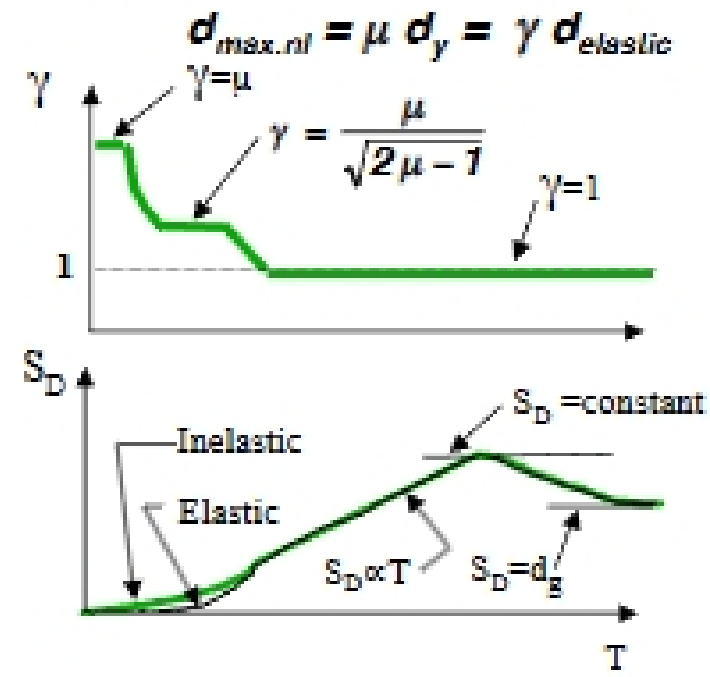
This can easily be plotted using conventional axes.



Note: $Q_y = S_{a,nl} m$
So: $d_y = S_{a,nl} / \omega^2$



To get maximum displacement



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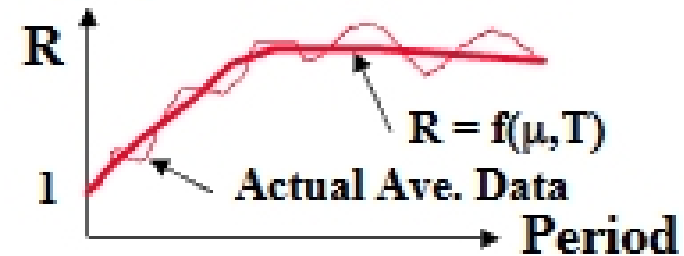
A Note on Displacement Estimates

$$\begin{aligned}
 \circ d_{max} &= \mu d_y = \mu Q_y / K \\
 &= \mu (Q_{elastic} / R) / K \\
 &= (\mu / R) (S_{Aelastic} M) / K \\
 &= (\mu / R) S_{Delastic} \\
 &= \gamma S_{Delastic}
 \end{aligned}$$

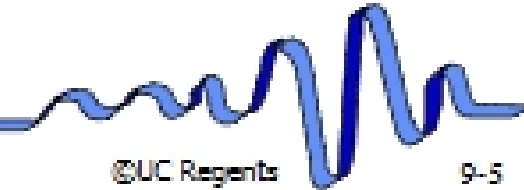
So: $\gamma = \mu / R$

Thus, if we have a relation that defines R as a function of μ [$R=f(\mu, T)$], we can estimate the maximum displacement using $\gamma = \mu / f(\mu, T)$,

- However, the R function does not exactly fit the data ($\mu_{actual} \neq \mu_{target}$), so if we use $\gamma = \mu_{target} / R$ our results will be slightly in error.



- We only have a few analytical expressions for $\gamma = f(\mu, T)$



Empirical Modification Factors for IDRS

Empirically derived equations have been developed to estimate R for a given displacement ductility demand on a structure.

Comprehensive review by: E. Miranda and V. Bertero in "Evaluation of Strength Reduction Factors for Earthquake-Resistant Design," *Earthquake Spectra*, EERI, Vol. 10, No. 2, 1994.

