Flow Activation Energy: Prediction Model For Compaction Effort

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Outline

- Review current state of the art: T_{mix} , T_{comp}
- Status of research Project NCHRP 9-39 @ NCAT July, 2005 to Dec 2007
- Kinetic model to predict compaction effort
- E_f : Flow activation energy
- E_f binder results: ranking compaction effort
- Conclusions and future research

Current Practice and methods

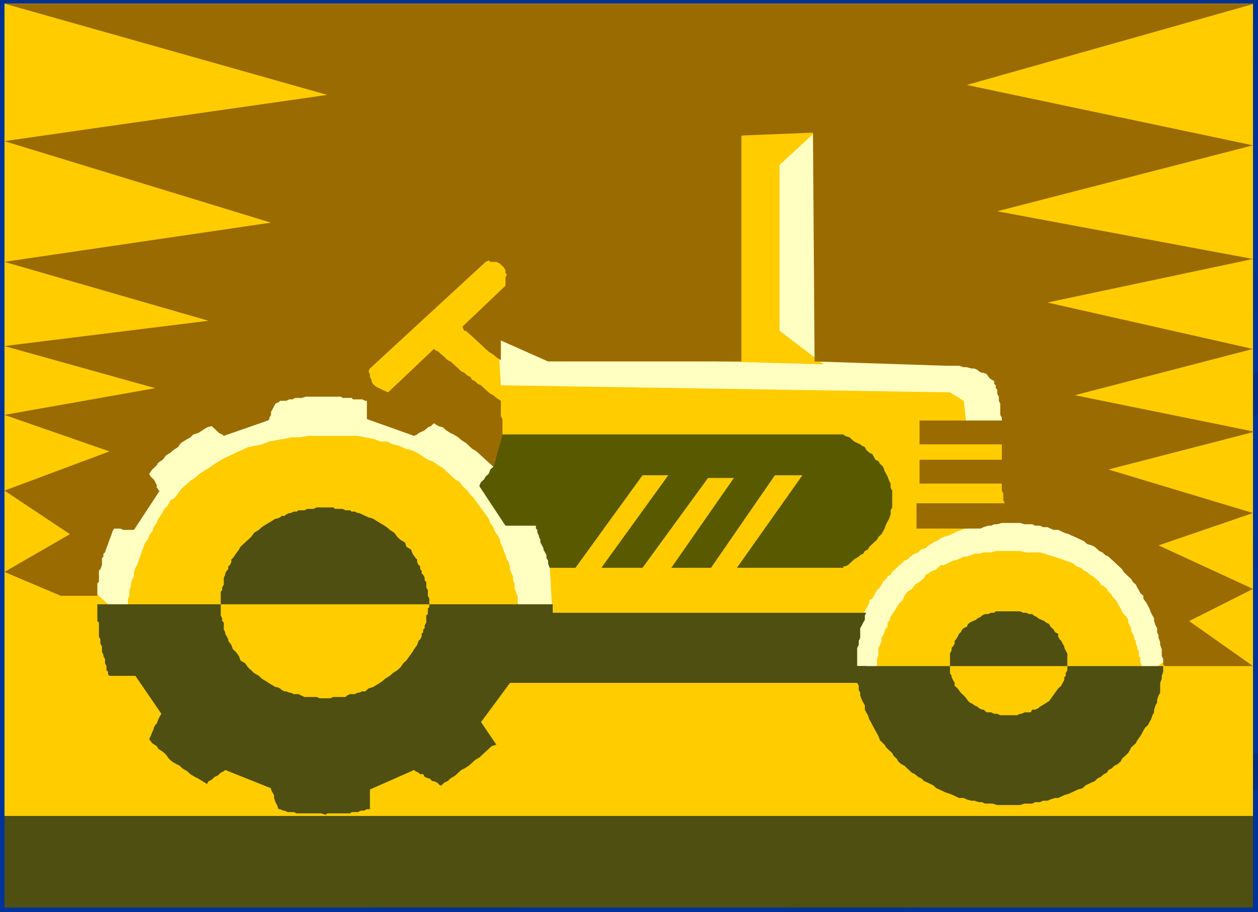
- Not many issues for unmodified binders
- T_{mix} , T_{comp} procedures per: AASHTO T245/T312; ASTM D2493; binder suppliers
- Low and high shear methods
- Final compaction temperature determined with a test strip.
- T_{mix} , T_{comp} for modified binders from Suppliers

Update from NCAT: NCHRP-9-39*: Determine T_{mix}, T_{comp} for Binders

- Review literature and survey DOT
- Steady Shear flow by DSR to 500 Pa
- High shear viscosity by rotational viscosity
- Evaluate binder phase angle with DSR
- Study 12 binders
- Determine shear resistance of mixes
- Validation and procedure

* Source NCAT/Randy West

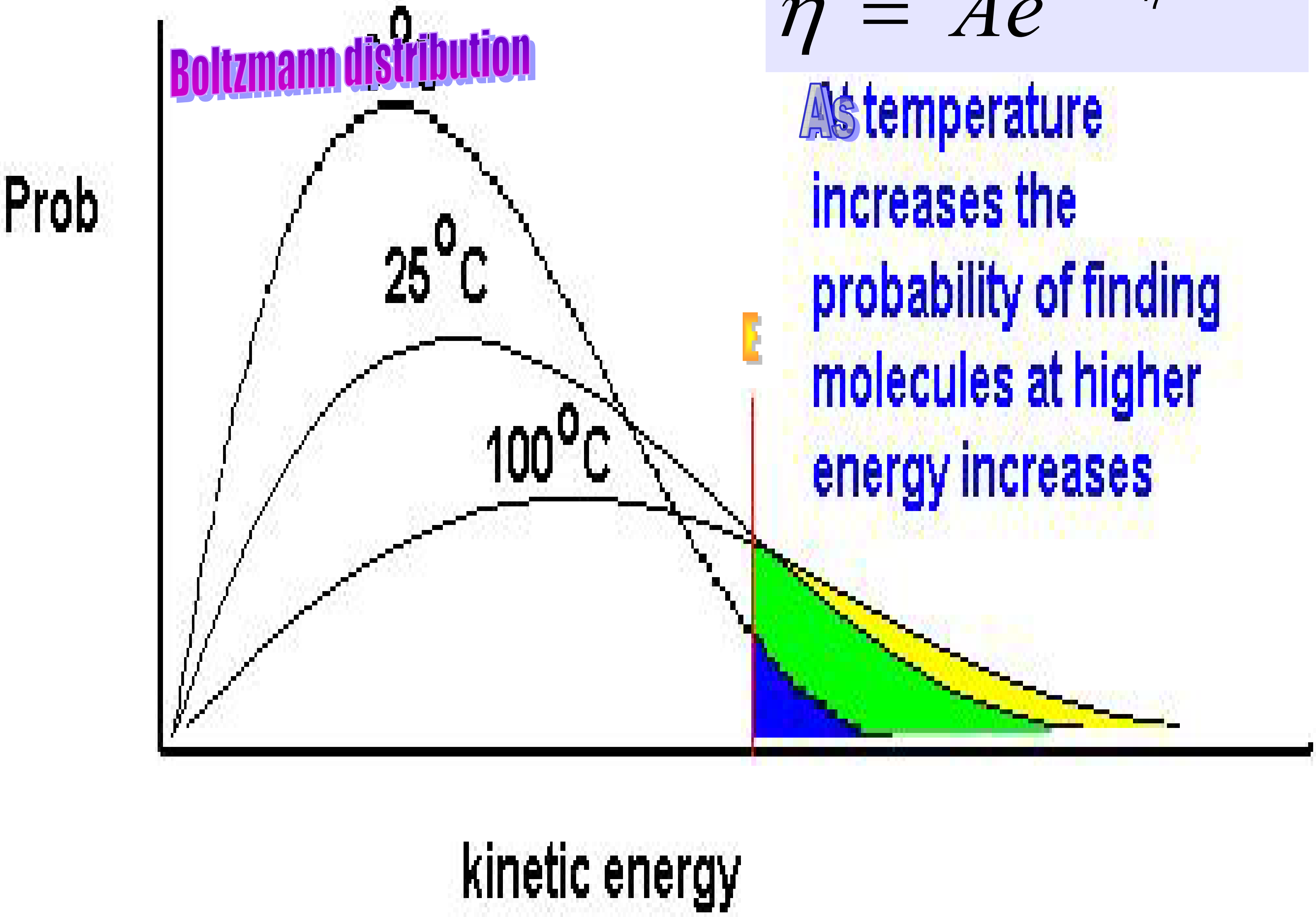
Another view on Compaction Effort



Kinetic model (Boltzmann distribution) and viscosity

- Viscosity is resistance to flow
- Intermolecular forces in liquid asphalt are responsible for resistance to flow
- Energy is needed to overcome resistance to flow
- Temperature is the property that tells us the direction of the flow of energy or a measure of the average kinetic energy of molecules

$$\eta = Ae^{\Delta E_\eta / RT}$$



As temperature increases the probability of finding molecules at higher energy increases

Boltzmann Distribution

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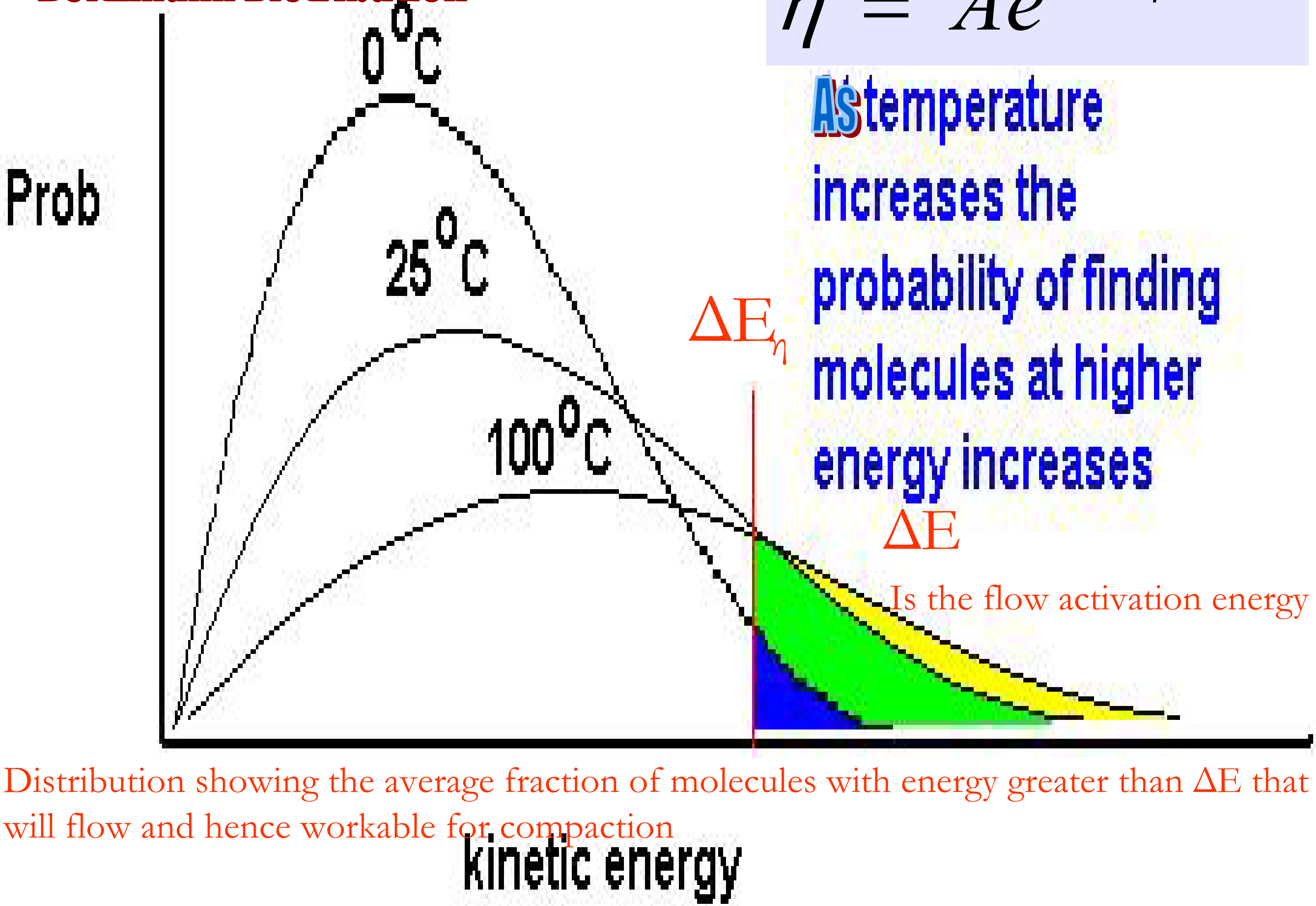


Distribution showing the average fraction of molecules with energy greater than ΔE that will flow and hence workable for compaction

Arrhenius Law

$$\eta = Ae^{\Delta E_{\eta} / RT}$$

ΔE_{η} : Activation Energy

R: Universal Gas Constant, 8.314 J/mol K

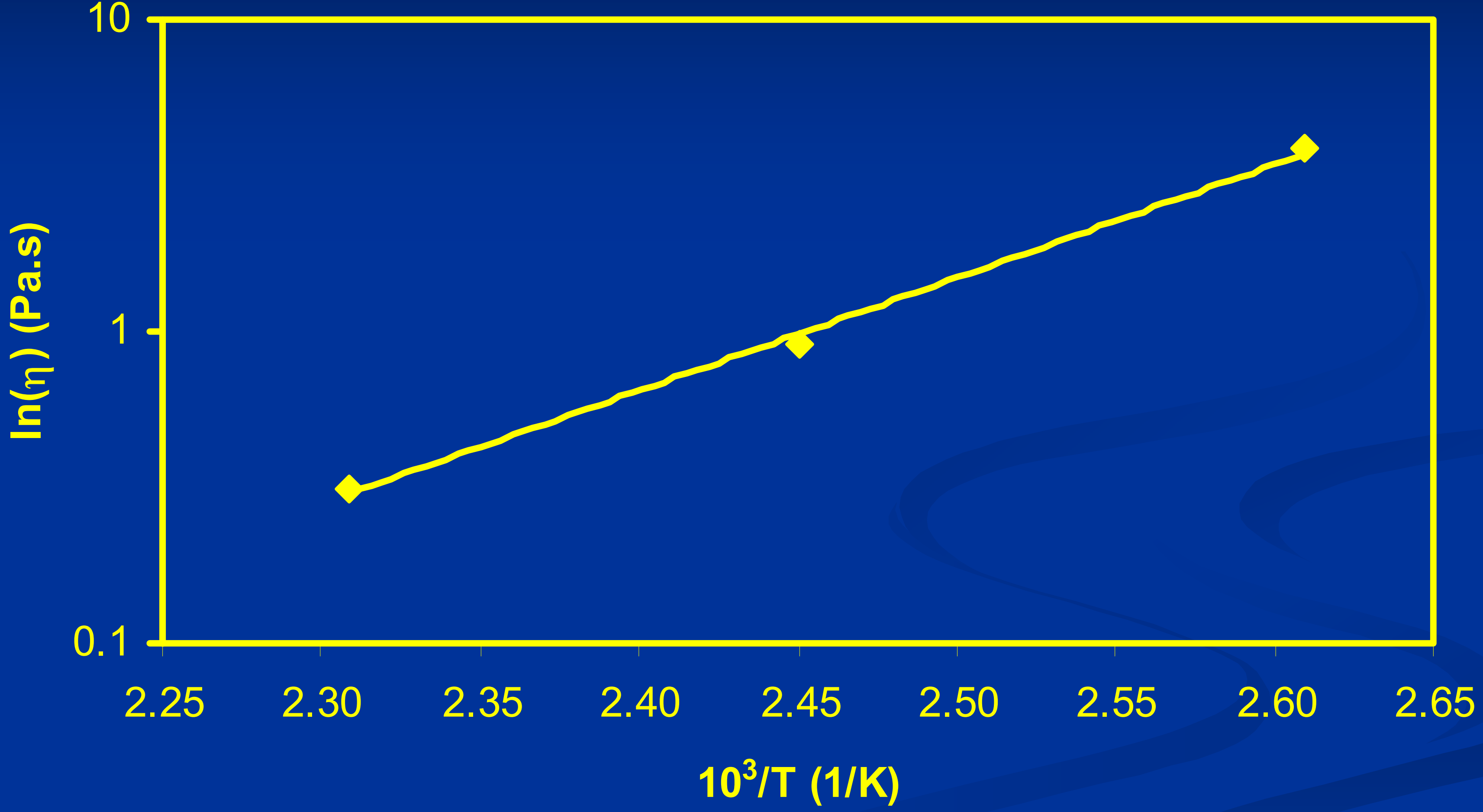
A: a constant

$$\ln \eta = \ln A + \frac{\Delta E_{\eta}}{RT}$$

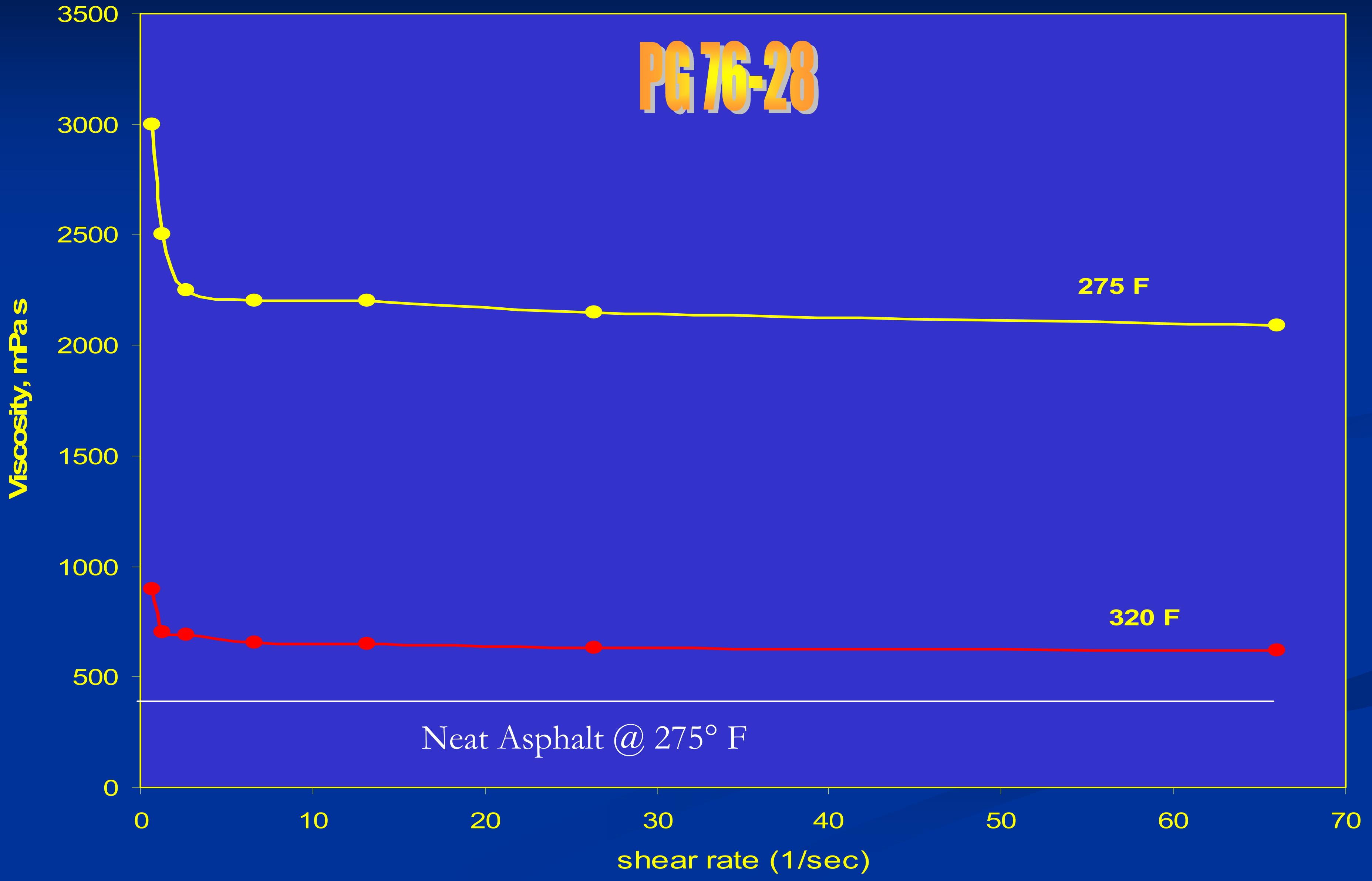
Ranking binders by flow activation energy, E_f

- Modify base asphalt, e.g. PG 64-28
- Determine viscosity at several temperatures
- Obtain high shear rate viscosity data
- Determine E_f from the Arrhenius equation
- Rank binders according to their flow activation energy

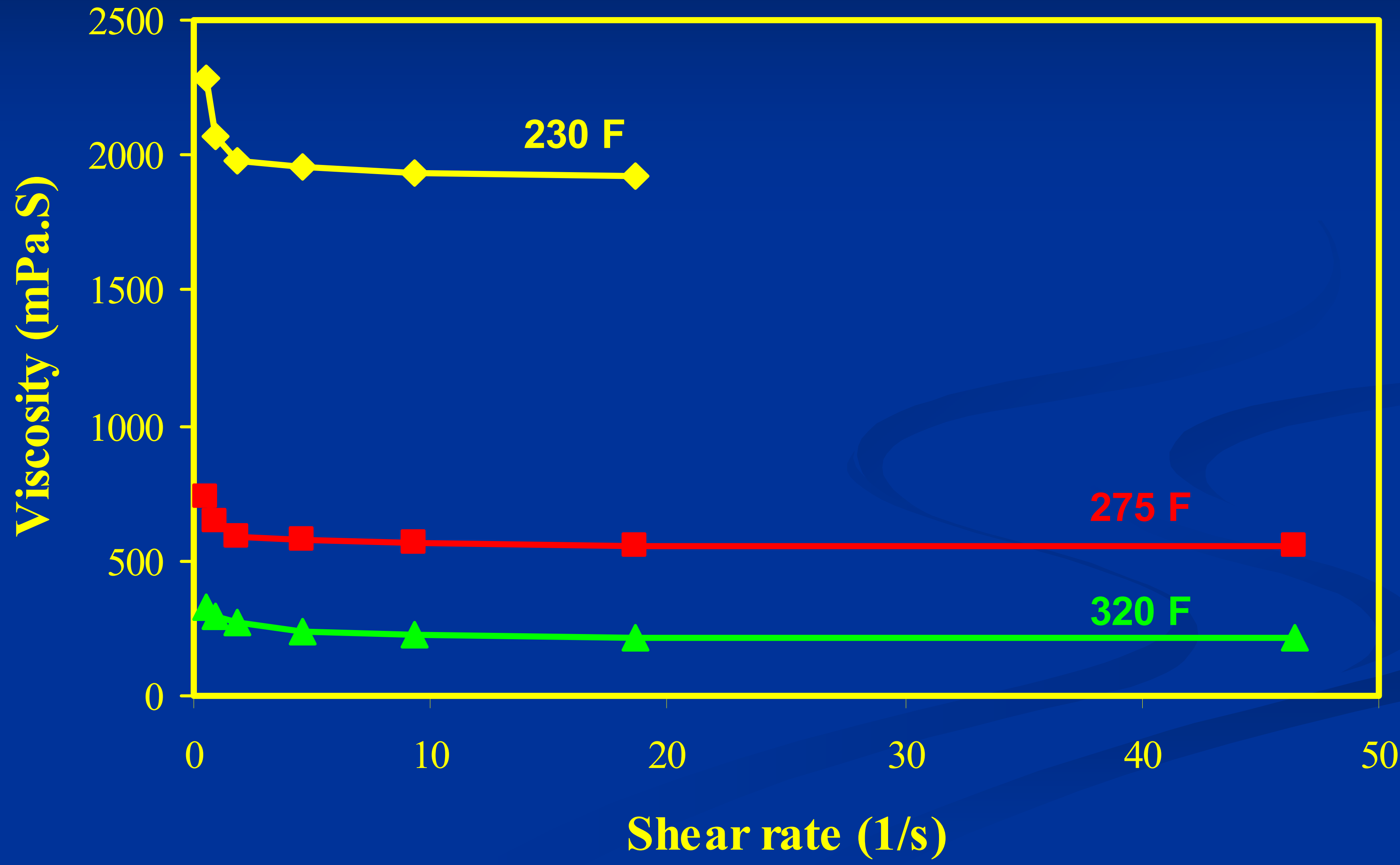
Typical Arrhenius plot for binders: viscosity measured at 110C(230F), 135C(275F), 160C(320F)



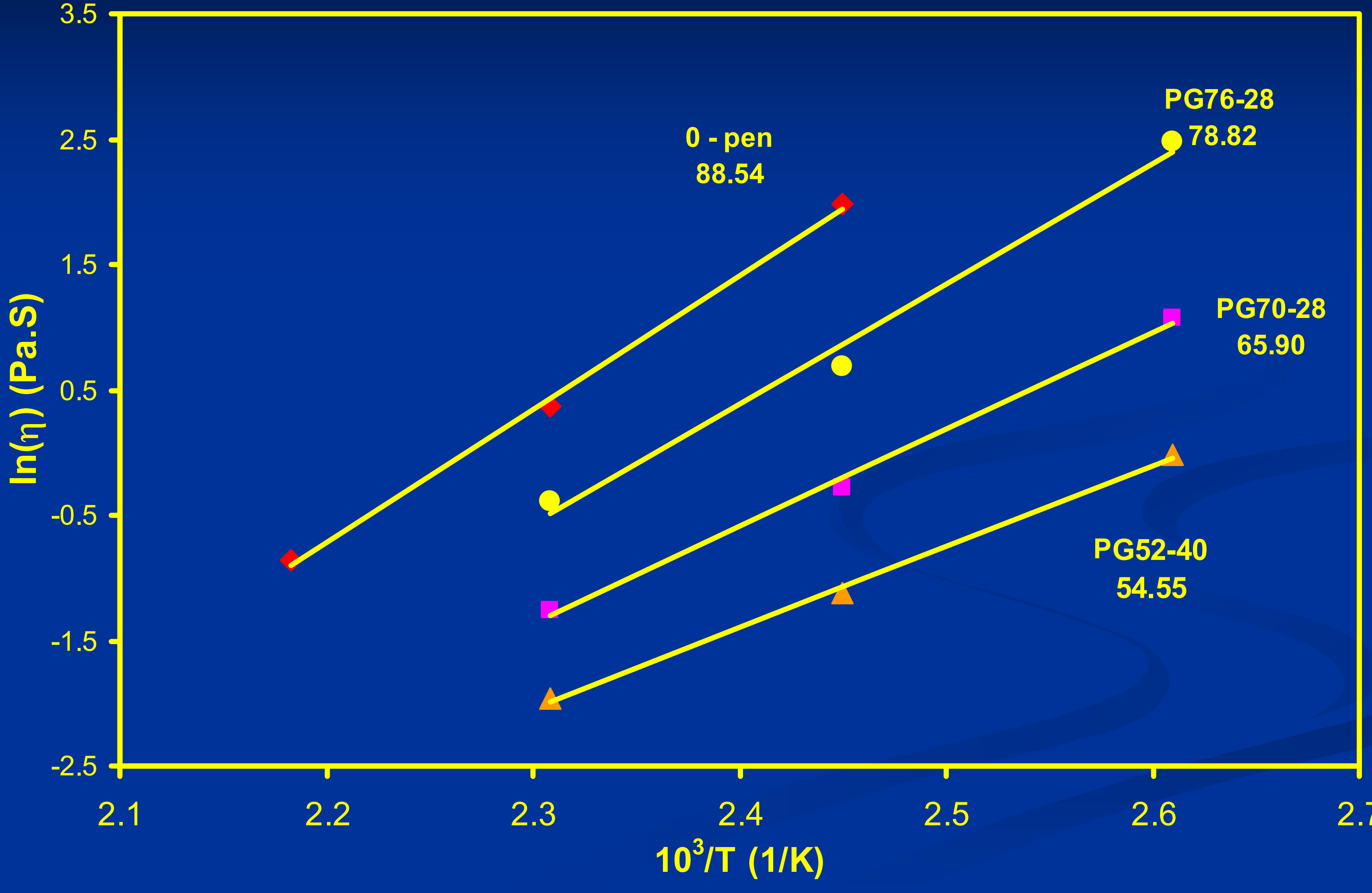
Typical viscosity shear rate dependence @ 320 F, 275 F



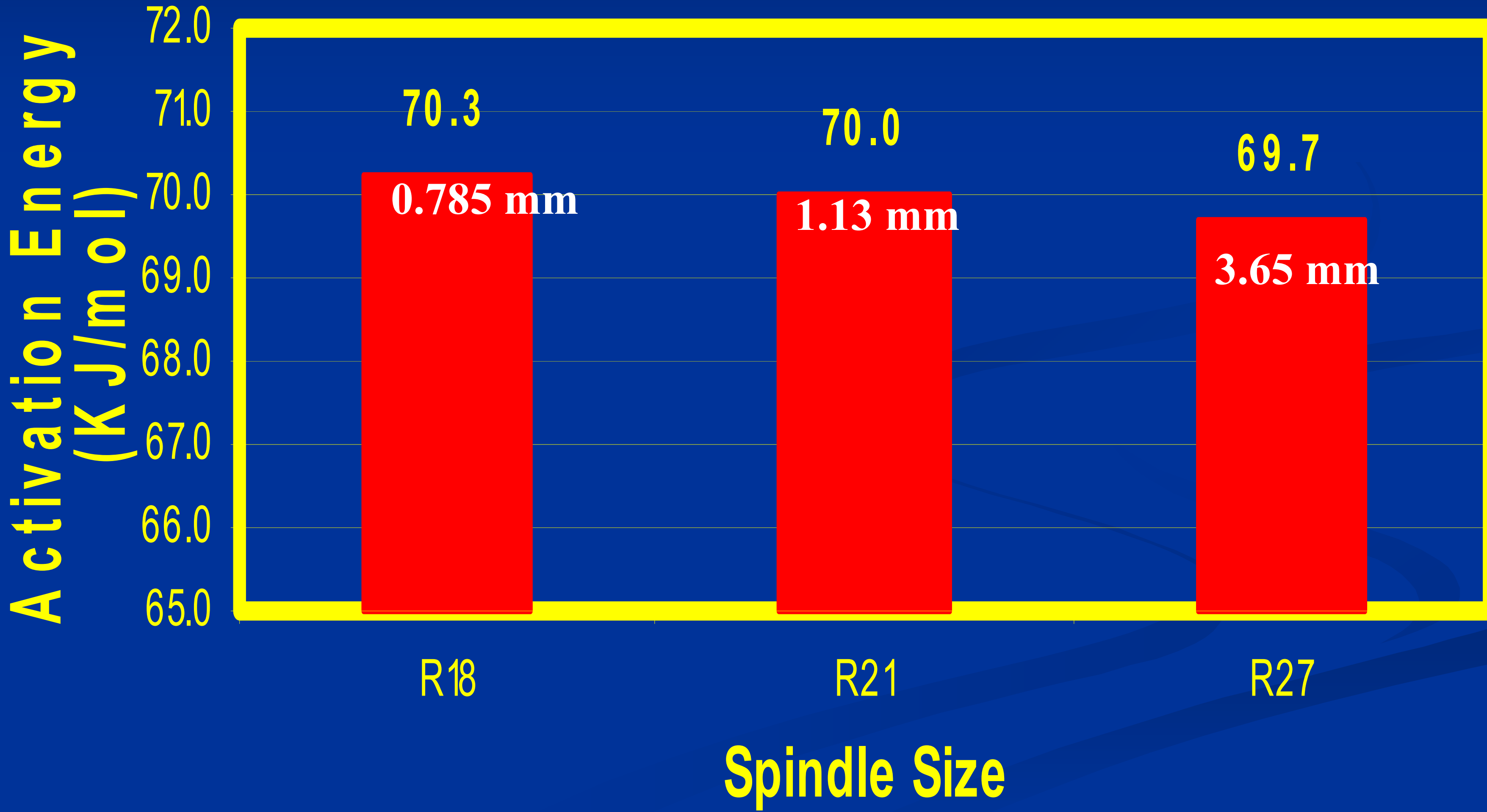
Viscosity-temperature Profile for PG 58-34



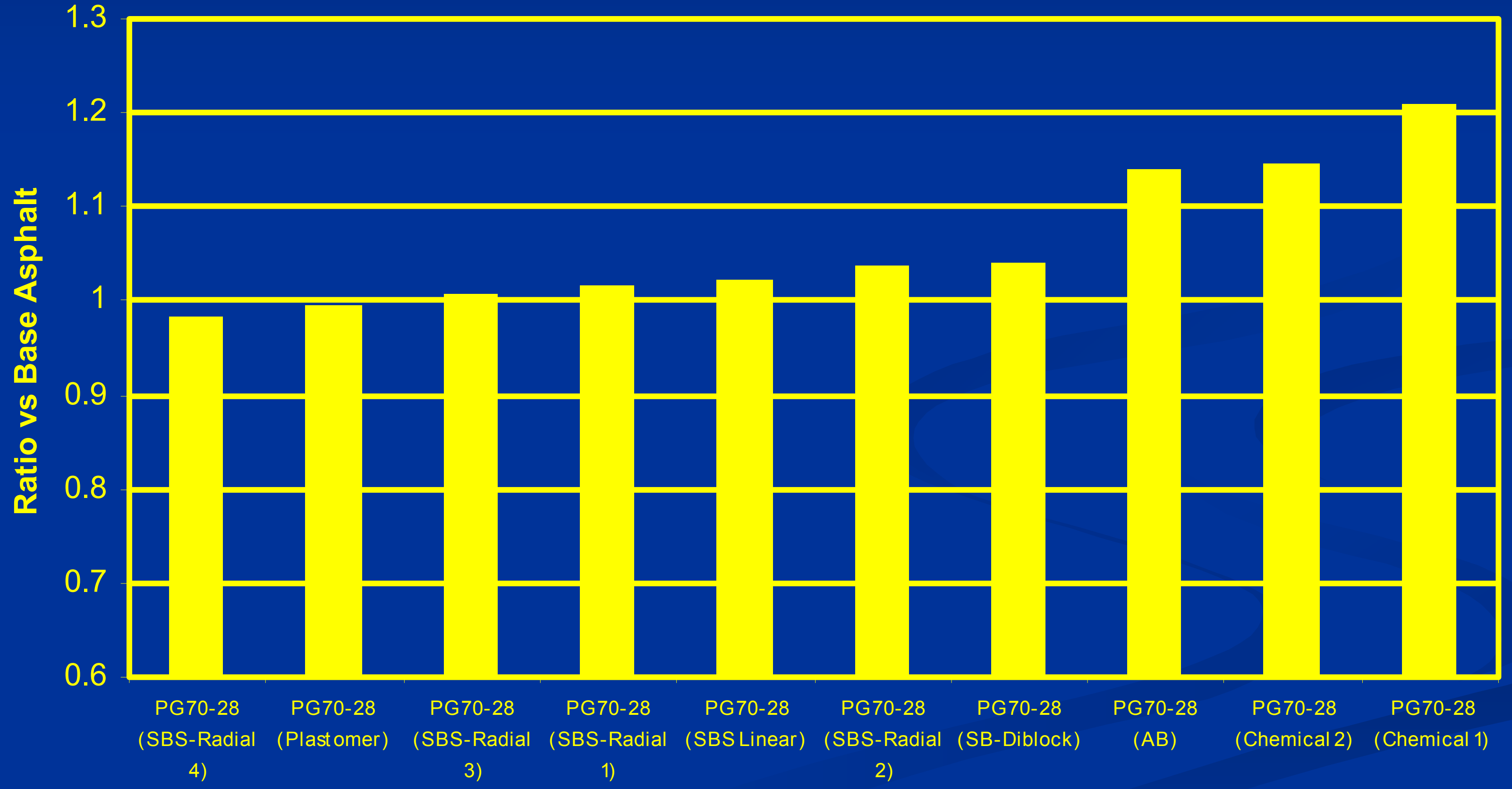
Arrhenius plot for various binders @110C(230F), 135C(275F), 160C(320F): flow activation energy



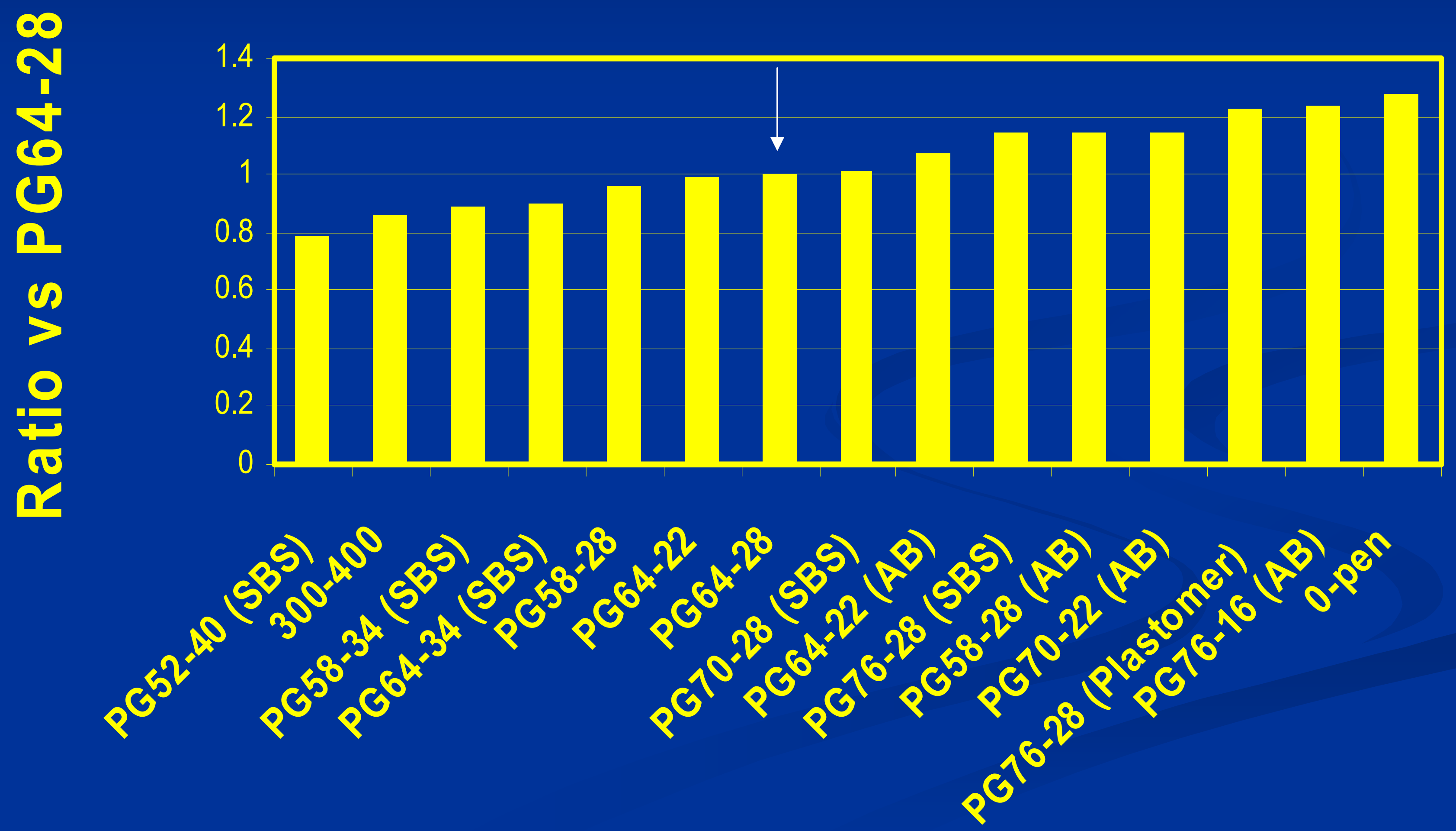
Activation Energy vs. "film thickness"



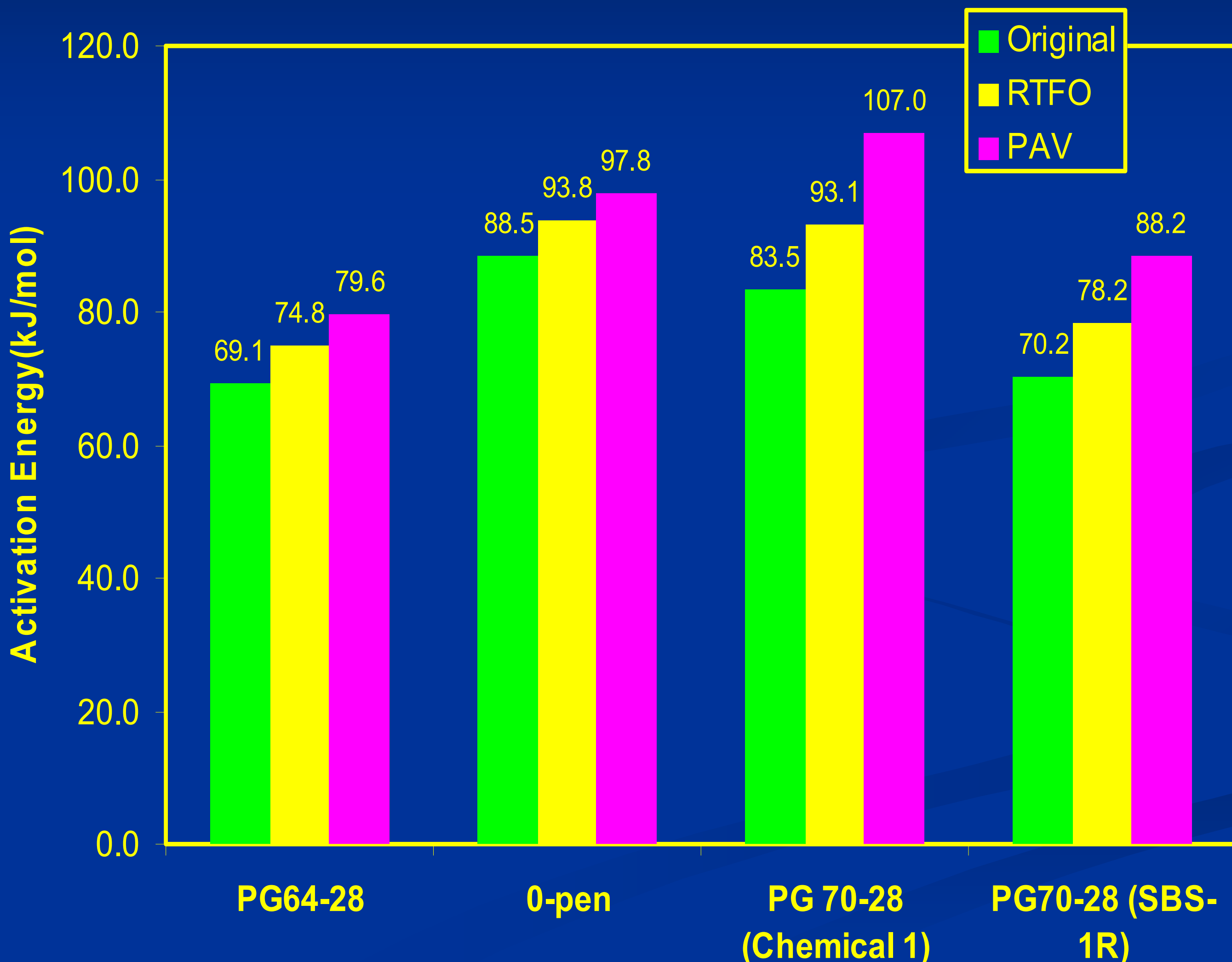
Effects of modifier types on the E_f for the same grade, PG70-28



Flow activation energy, E_f , for different binders relative to PG64-28



Effect of aging on the flow activation energy



Conclusions and future research

- The kinetic model (Boltzmann distribution) is proposed as a model for understanding compaction effort of binders
- The Arrhenius law, $\ln \eta = A + E_f/RT$ is used to obtain E_f
- The magnitude of E_f is governed by the <u>intermolecular forces</u> between molecules of the liquid binder and explains the viscosity differences of binders
- The use of flow activation energy provides a procedure for predicting rational compaction effort of a mix.
- Shear resistance of the mix obtained from SGC would offer a more complete description of compaction effort.