

# Asphalt 101:

## An Introduction to Hot Mix Asphalt Materials

-Part I-

## Asphalt and Modified Asphalts

**Asphalt 101:**

**An Introduction to  
Hot Mix Asphalt  
Materials**

**-Part I-**

**Asphalt and  
Modified Asphalts**

**Scott Shuler**

**CSU**



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Glue:  
*Scott Shuler*

Sticky Glue:  
*Marshall Shackelford*

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# Why Study Asphalt?

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**of all the ROADS IN THE U. S. A.  
(miles)**

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of all the **ROADS IN THE U. S. A.**  
(miles)

100,000



Concrete

Earth

Gravel

Asphalt

# Why Study Asphalt?

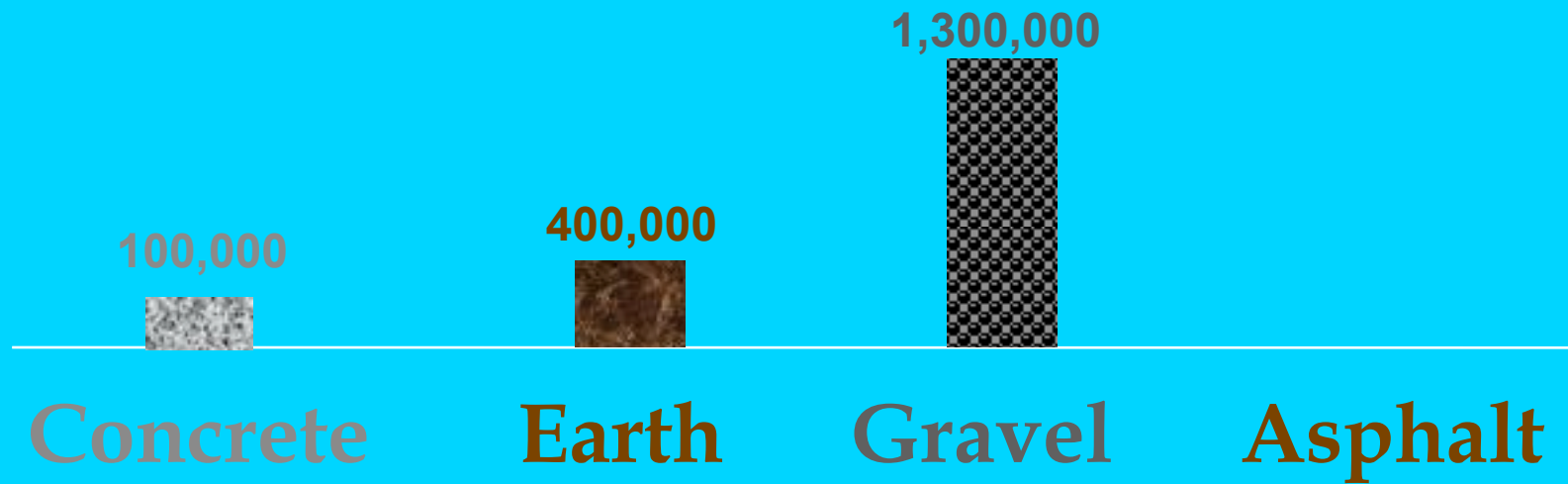
of all the **ROADS IN THE U. S. A.**  
(miles)





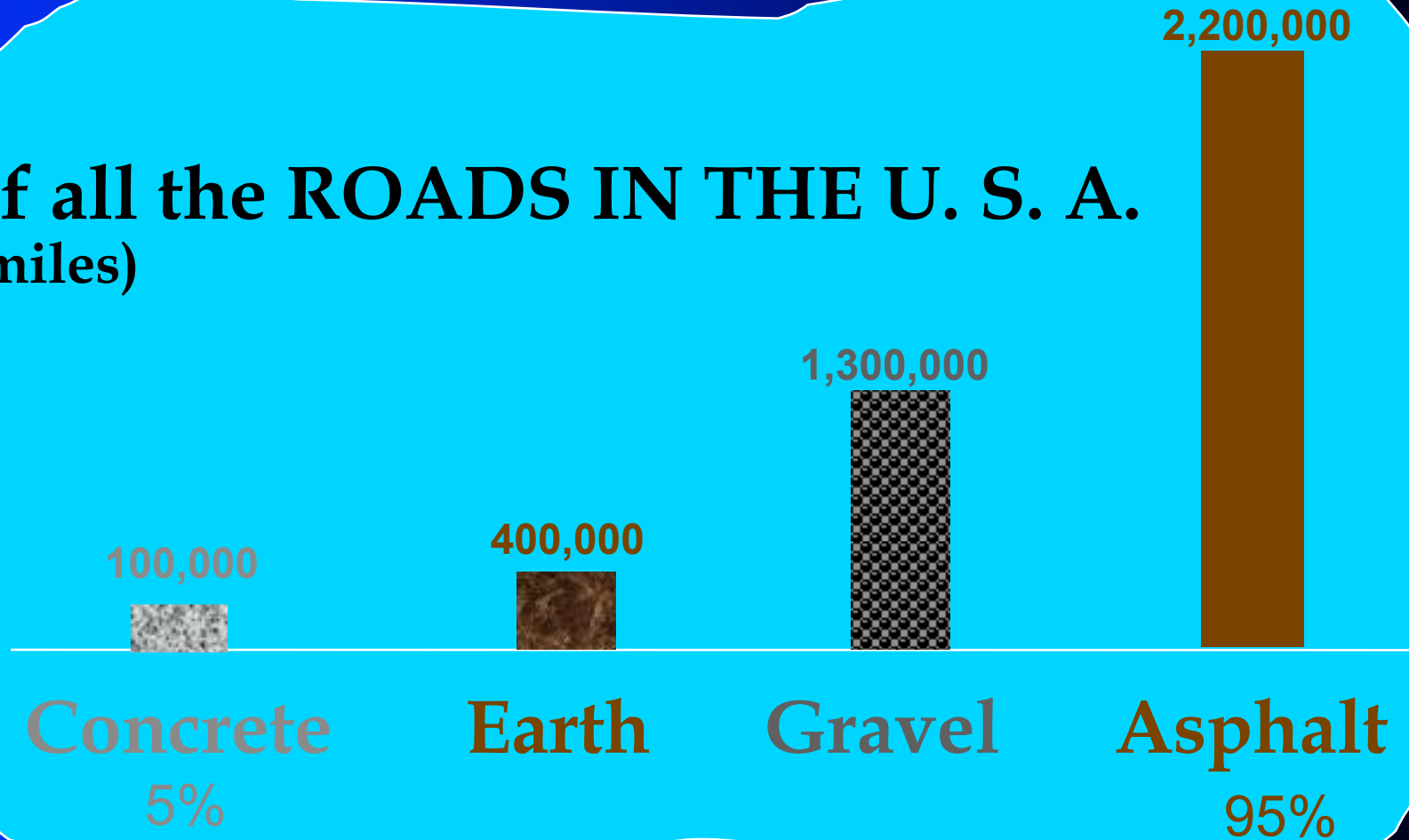
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- Hot Mix Asphalt Placed Annually
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  - \$10.5 Billion
- Employment
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  - 600,000 additionally
- Asphalt is Largely Empirical
  - “Old Timers” Retiring

# What Are Asphalt Pavements ?

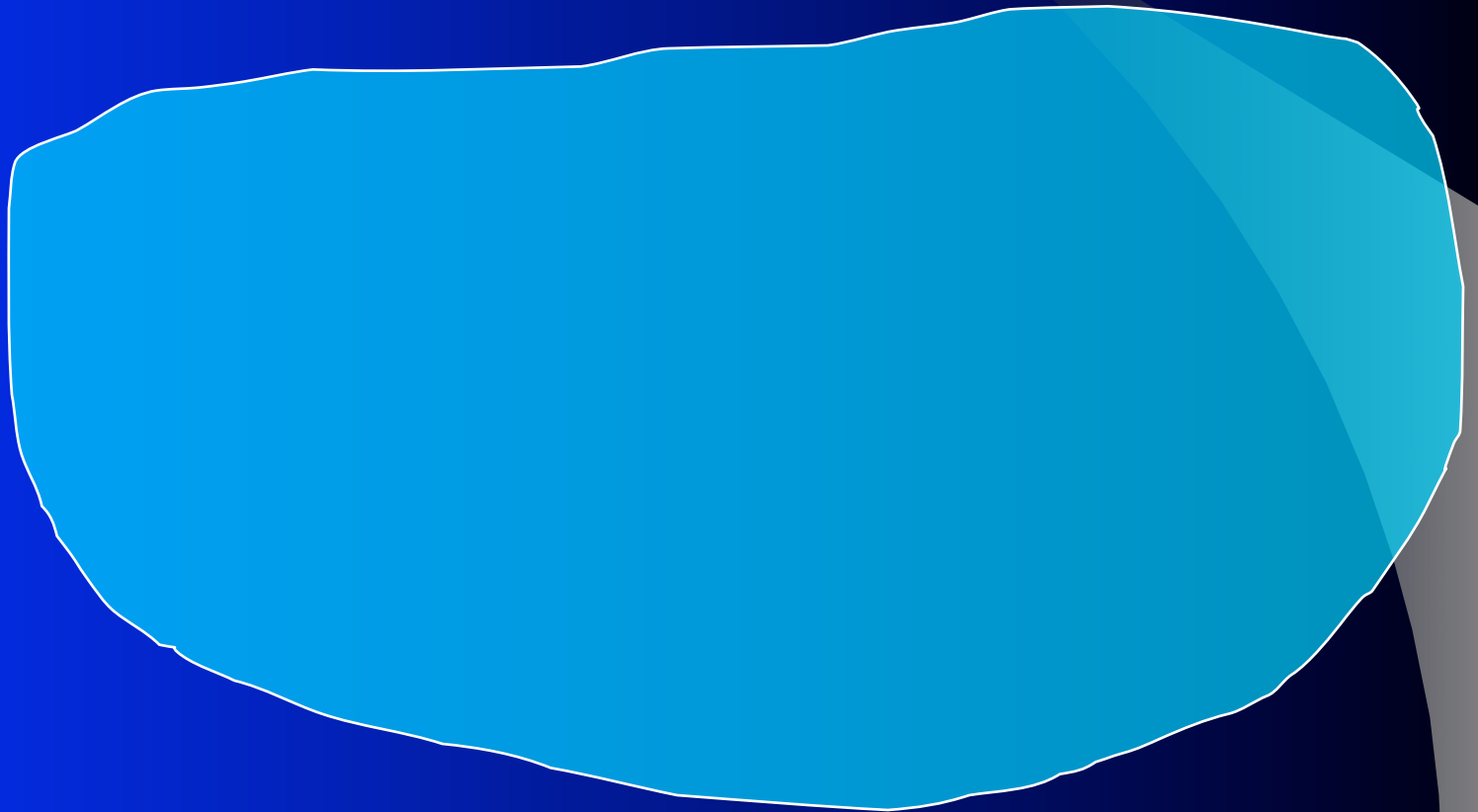


# What Are Asphalt Pavements ?

- Rocks Glued Together With Asphalt

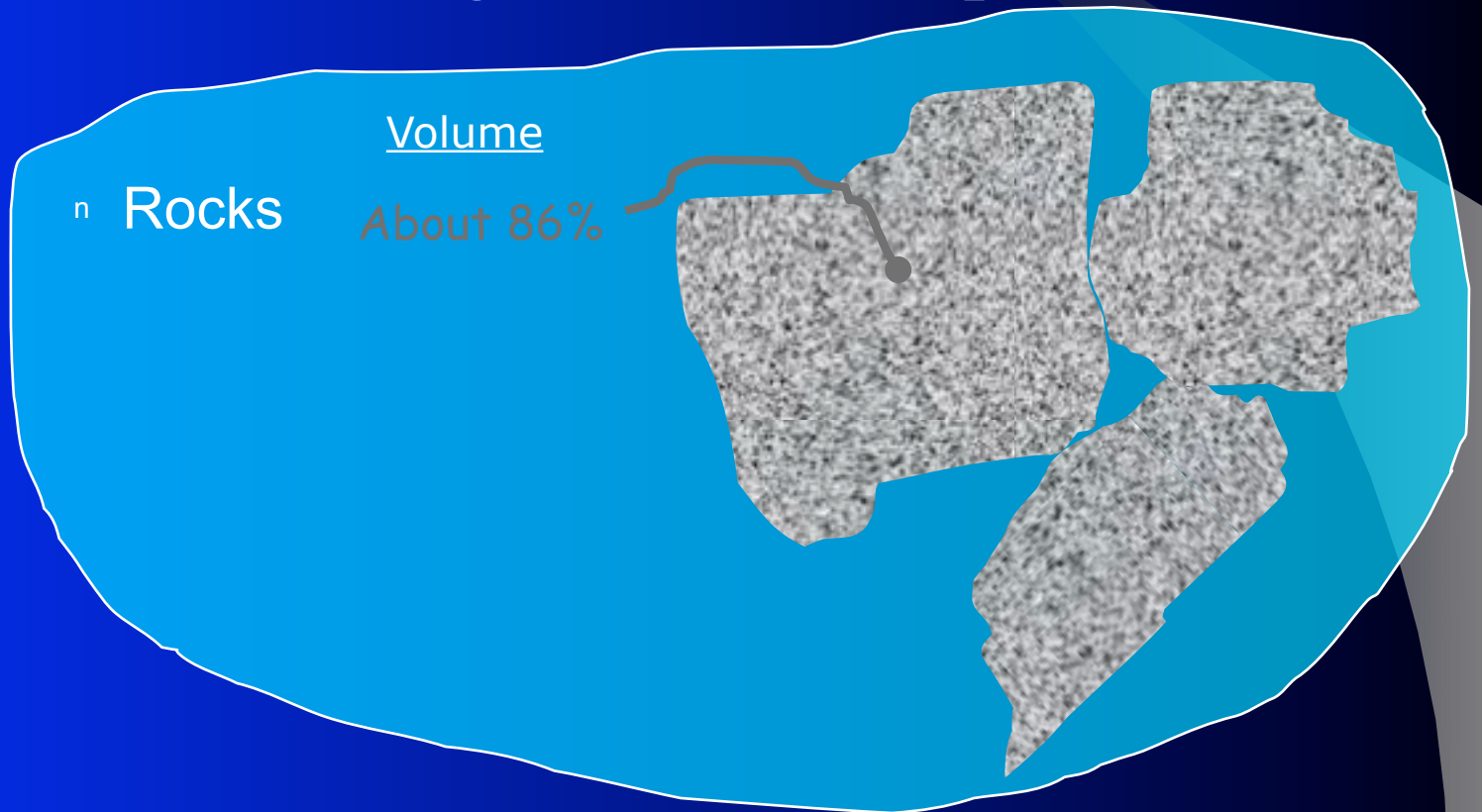
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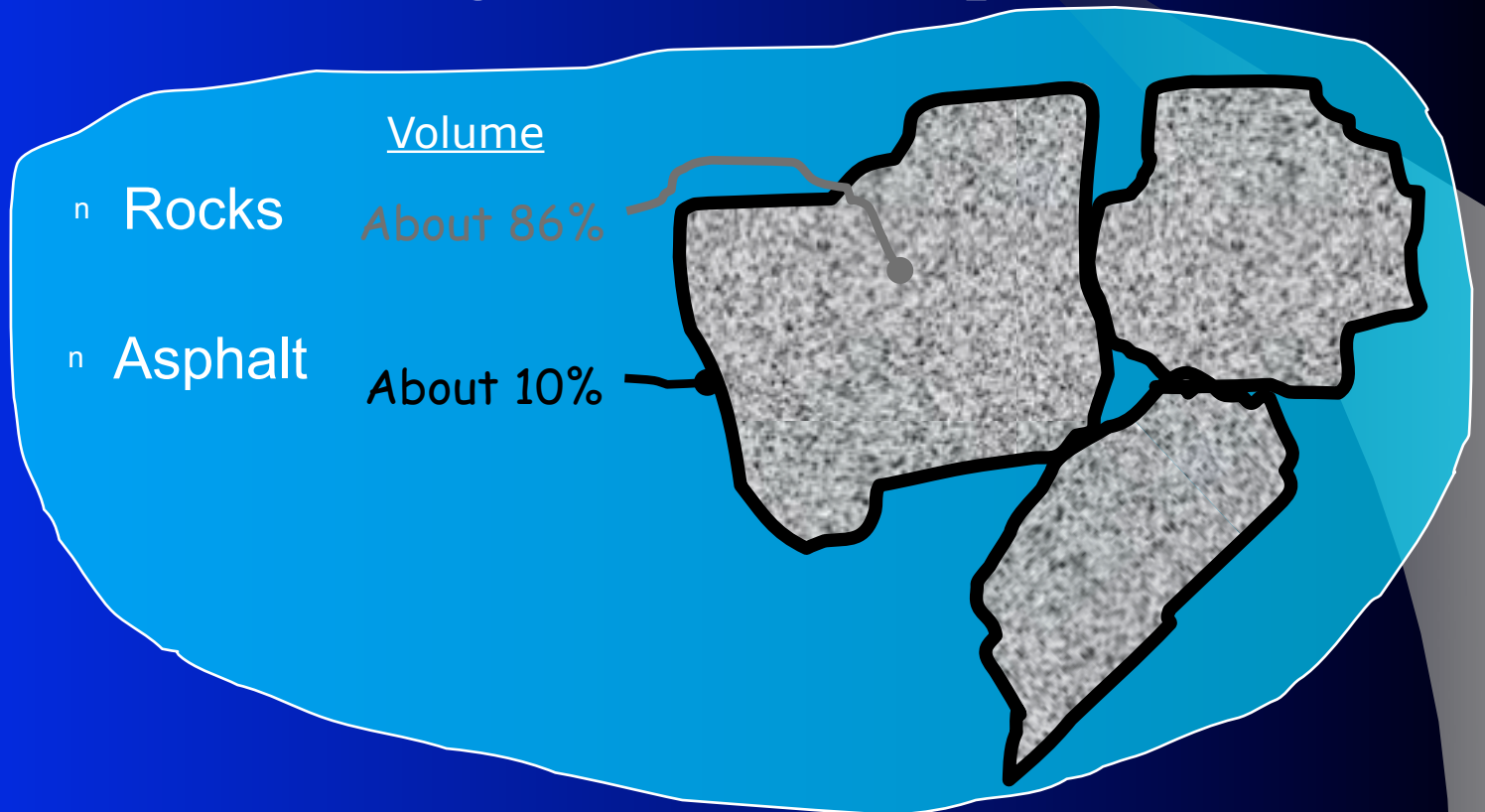
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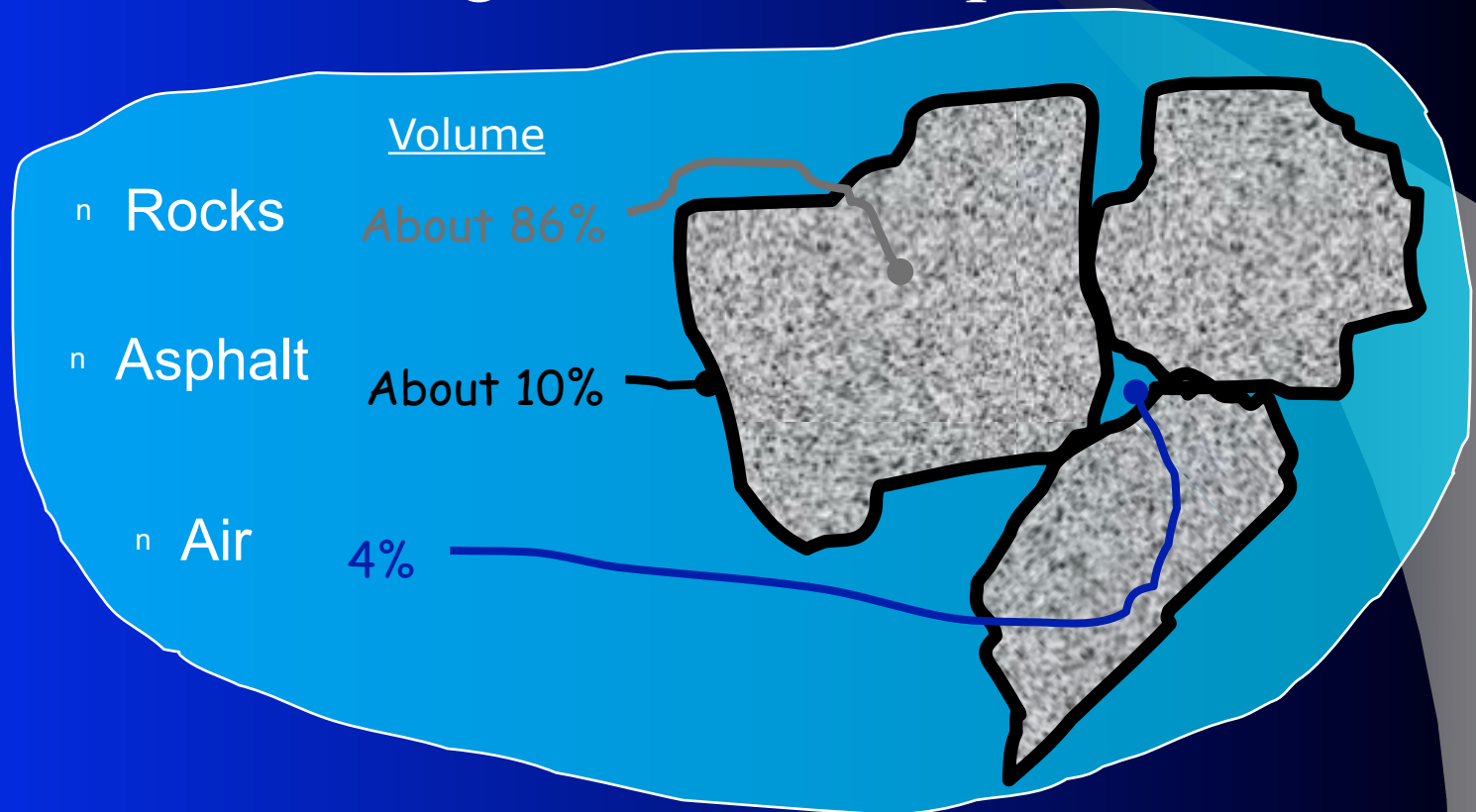
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  - Roman Buildings Waterproofed and Cemented
    - Romans called the source *Lacus Asphaltites*

So It Will Work!

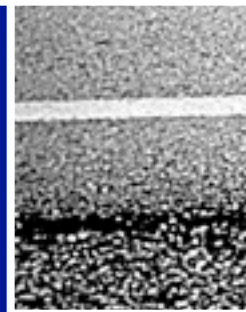
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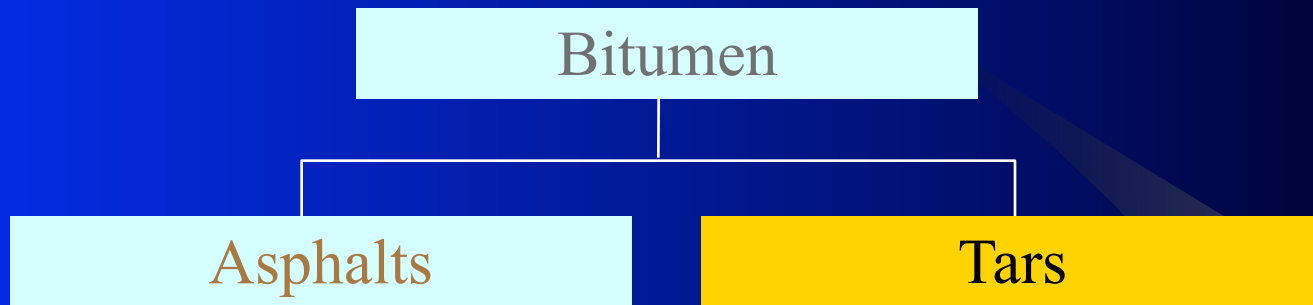
# Reed Boat, aka *Gufa*

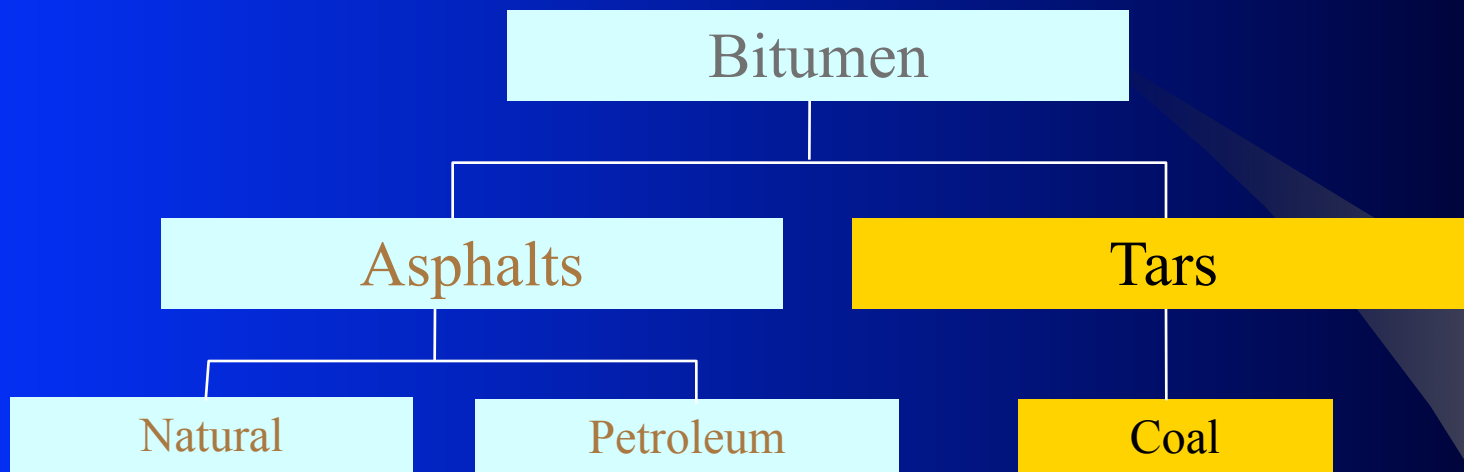






Bitumen





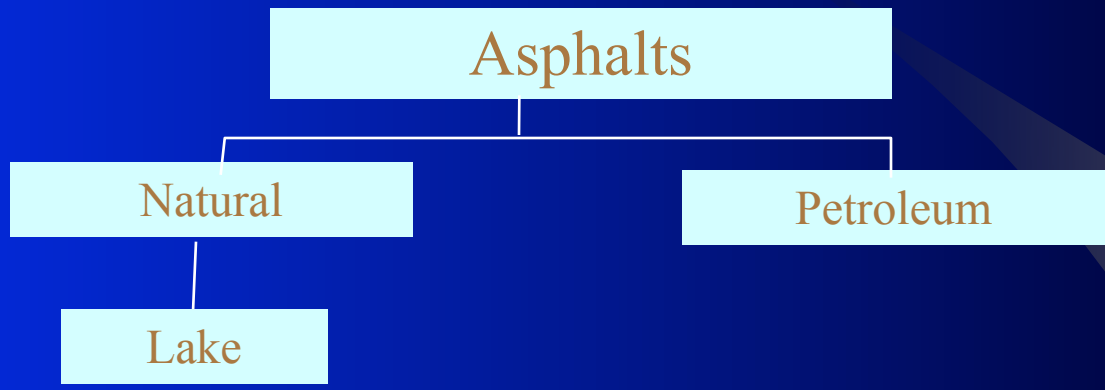
# Asphalts

Asphalts

```
graph TD; A[Asphalts] --> B[Natural]; A --> C[Petroleum]
```

Natural

Petroleum



Asphalts

Natural

Petroleum

Trinidad

Lake



# Asphalts

Natural

Petroleum

Trinidad

La Brea

Lake

# Asphalts

Natural

Petroleum

Trinidad

La Brea

Lake

Rock

# Asphalts

Natural

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KY

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KY

TX

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KY

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Asphaltites

# Asphalts

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Petroleum

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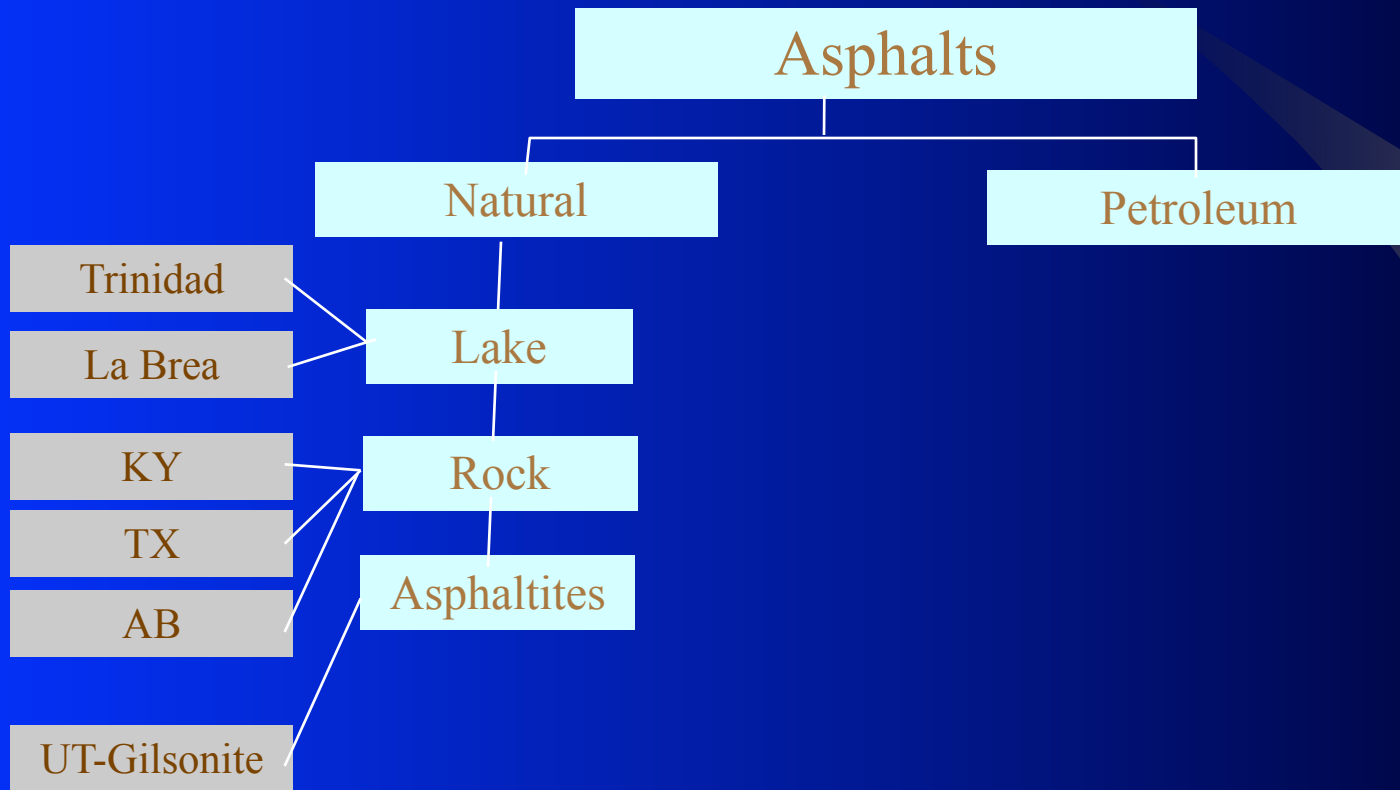
AB

UT-Gilsonite

Lake

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# Asphalts

Natural

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Lake

Rock

Asphaltites

Cements

Liquids



# Asphalts

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Lake

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Asphaltites

Trinidad

La Brea

KY

TX

AB

UT-Gilsonite

Petroleum

Cements

Liquids

Emulsions

Cutbacks

# Crude Oil Variations

# Crude Oil Variations

Venezuelan

Nigerian Light

# Crude Oil Variations

Venezuelan

Gasoline 3%

Nigerian Light

Gasoline 33%

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Venezuelan

Gasoline 3%

Kerosene 6%

Nigerian Light

Gasoline 33%

Kerosene  
20%

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Kerosene 6%

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## Nigerian Light

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Kerosene  
20%

Gas Oil 46%

# Crude Oil Variations

## Venezuelan

Gasoline 3%

Kerosene 6%

Gas Oil 33%

Residuum  
58%

## Nigerian Light

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Gas Oil 46%

Residuum 1%

# Refining Methods



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- Distillation
  - Atmospheric
  - Vacuum

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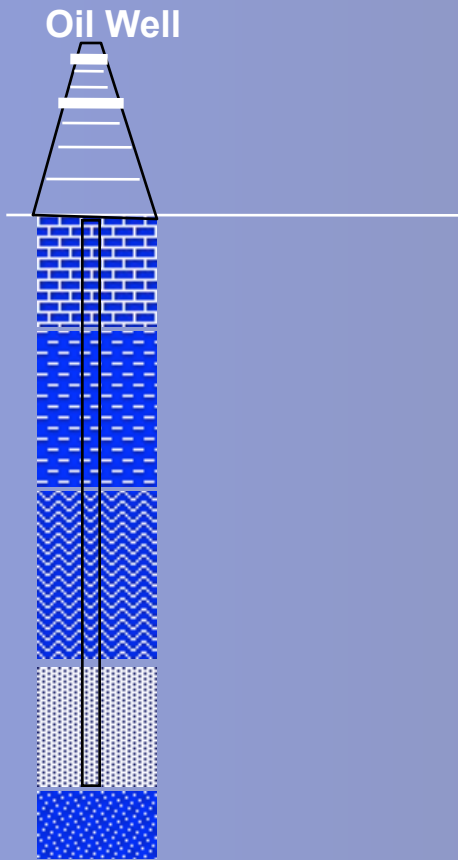
- Distillation
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- Solvent Deasphalting
  - Propane and Butane Extraction of Lube Oils
  - Result is Very Hard Precipitate AC

# Refining Methods

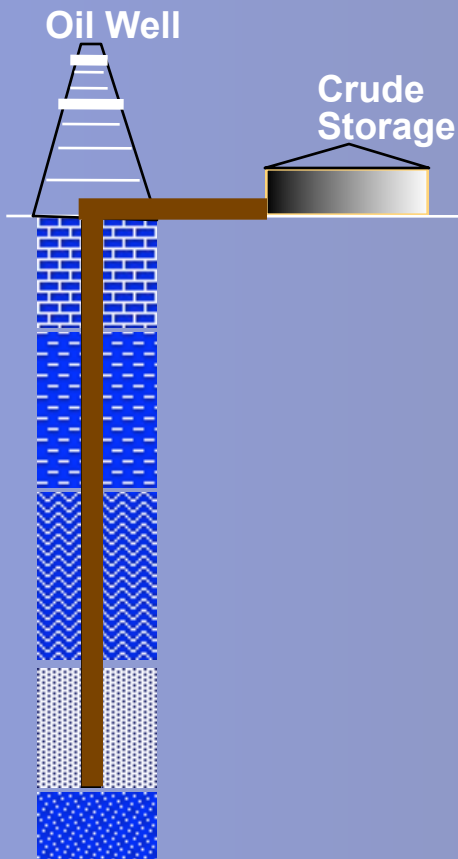
- Distillation
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  - Vacuum
- Solvent Deasphalting
  - Propane and Butane Extraction of Lube Oils
  - Result is Very Hard Precipitate AC
- Solvent Extraction (ROSE)
  - Separates AC into Asphaltenes/Resins/Oils
  - Result is Blended to Produce Spec AC

# Petroleum Asphalts

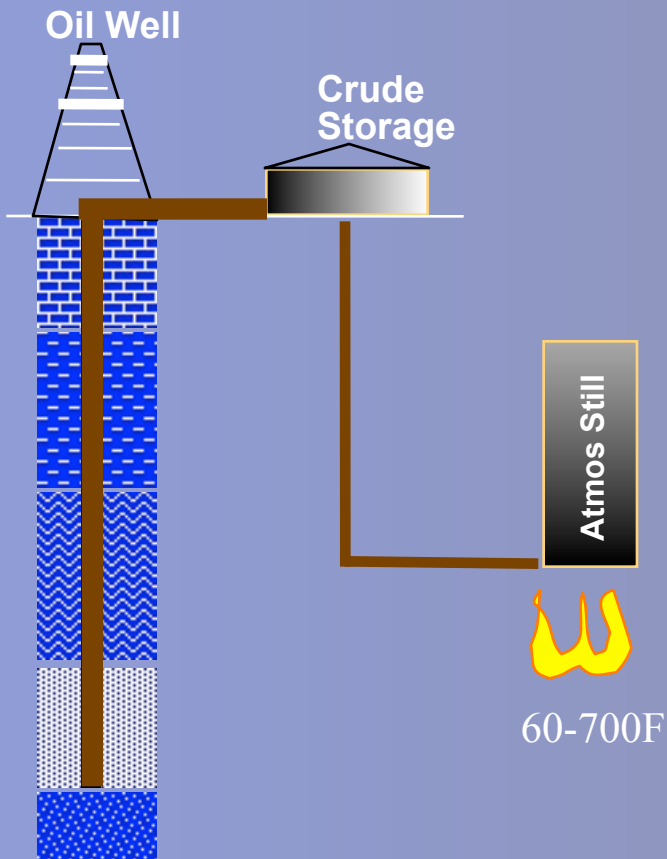
# Petroleum Asphalts



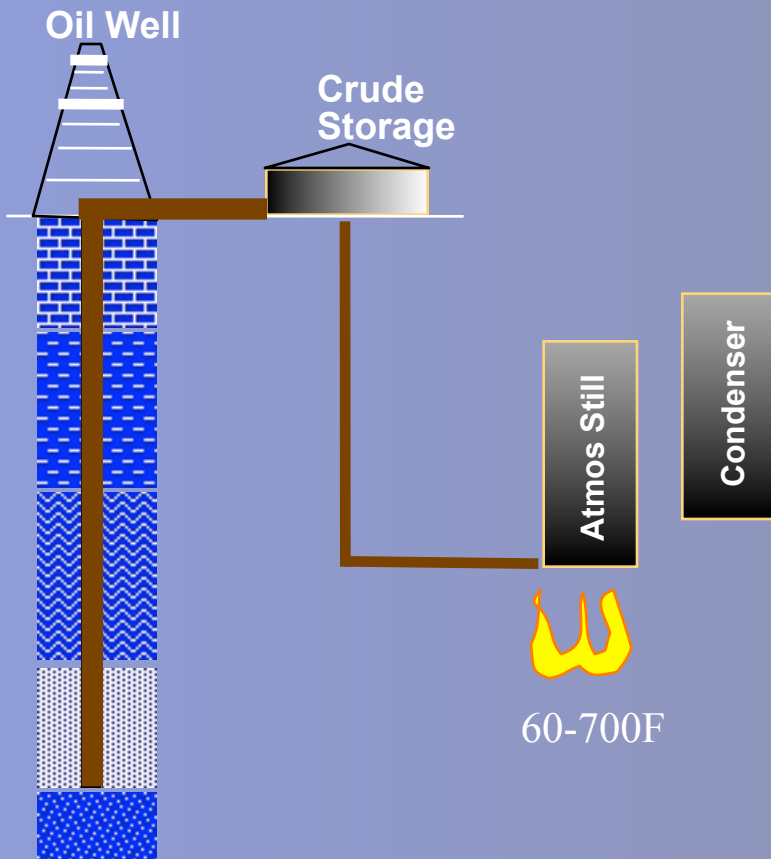
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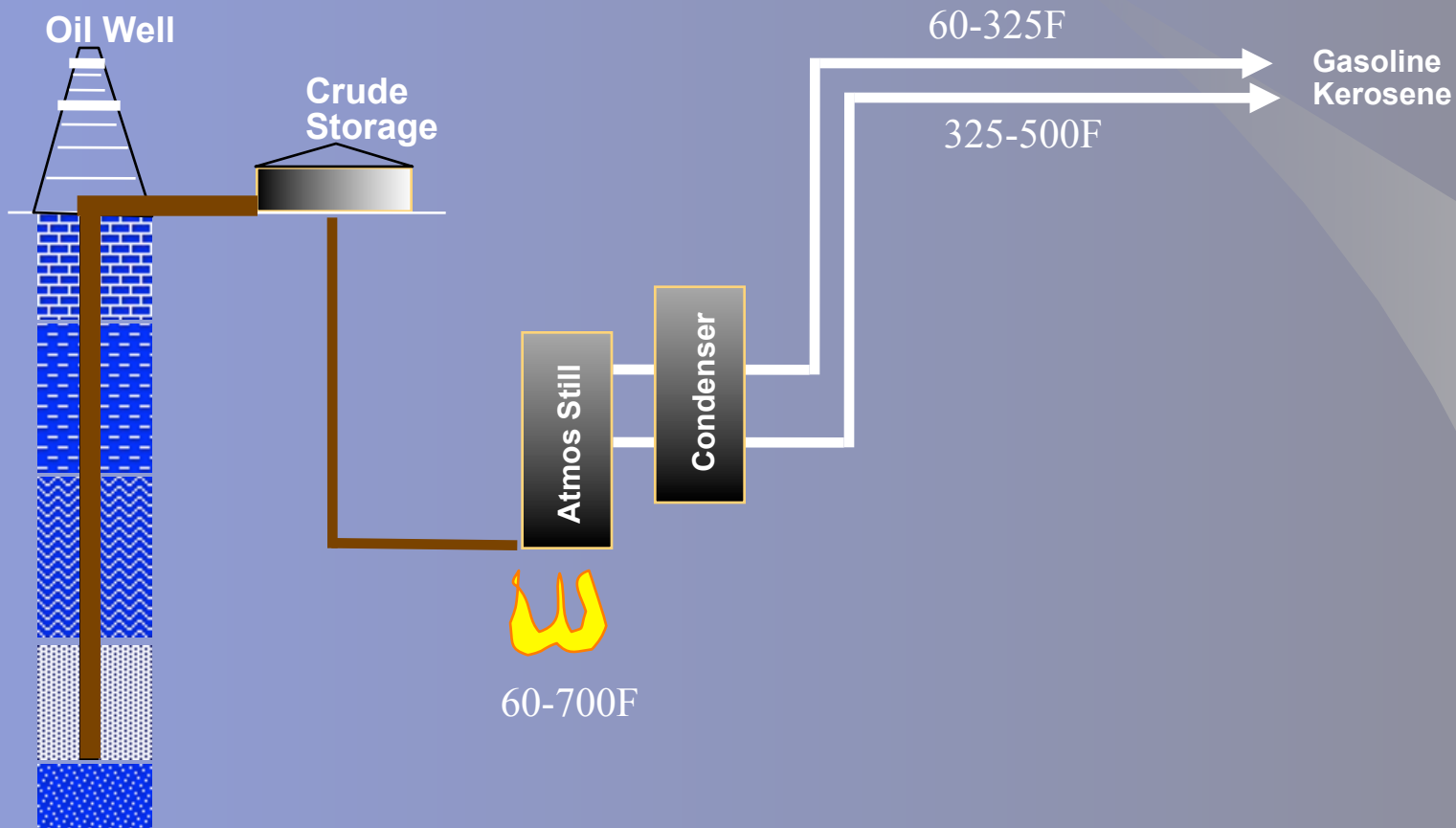


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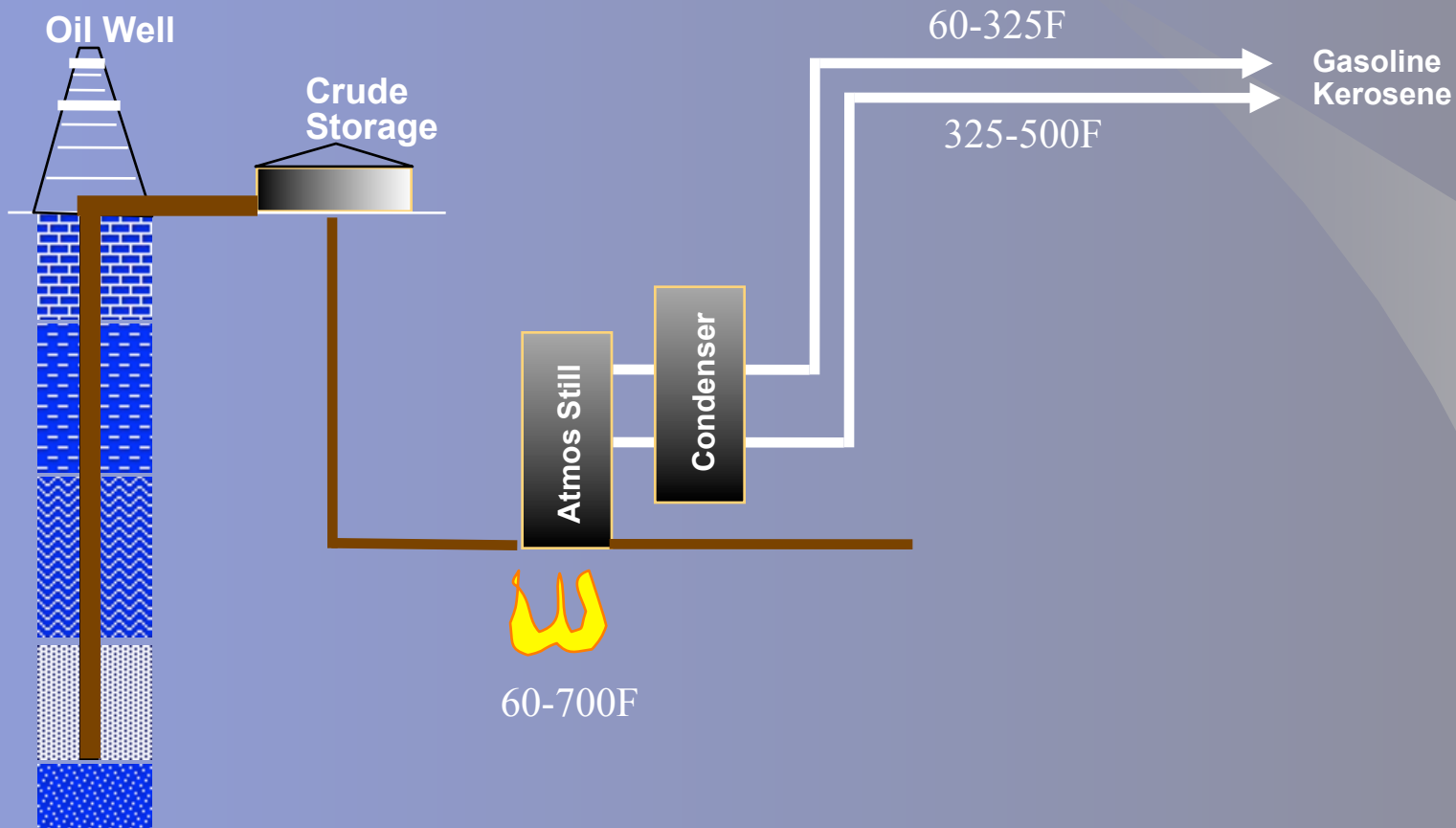




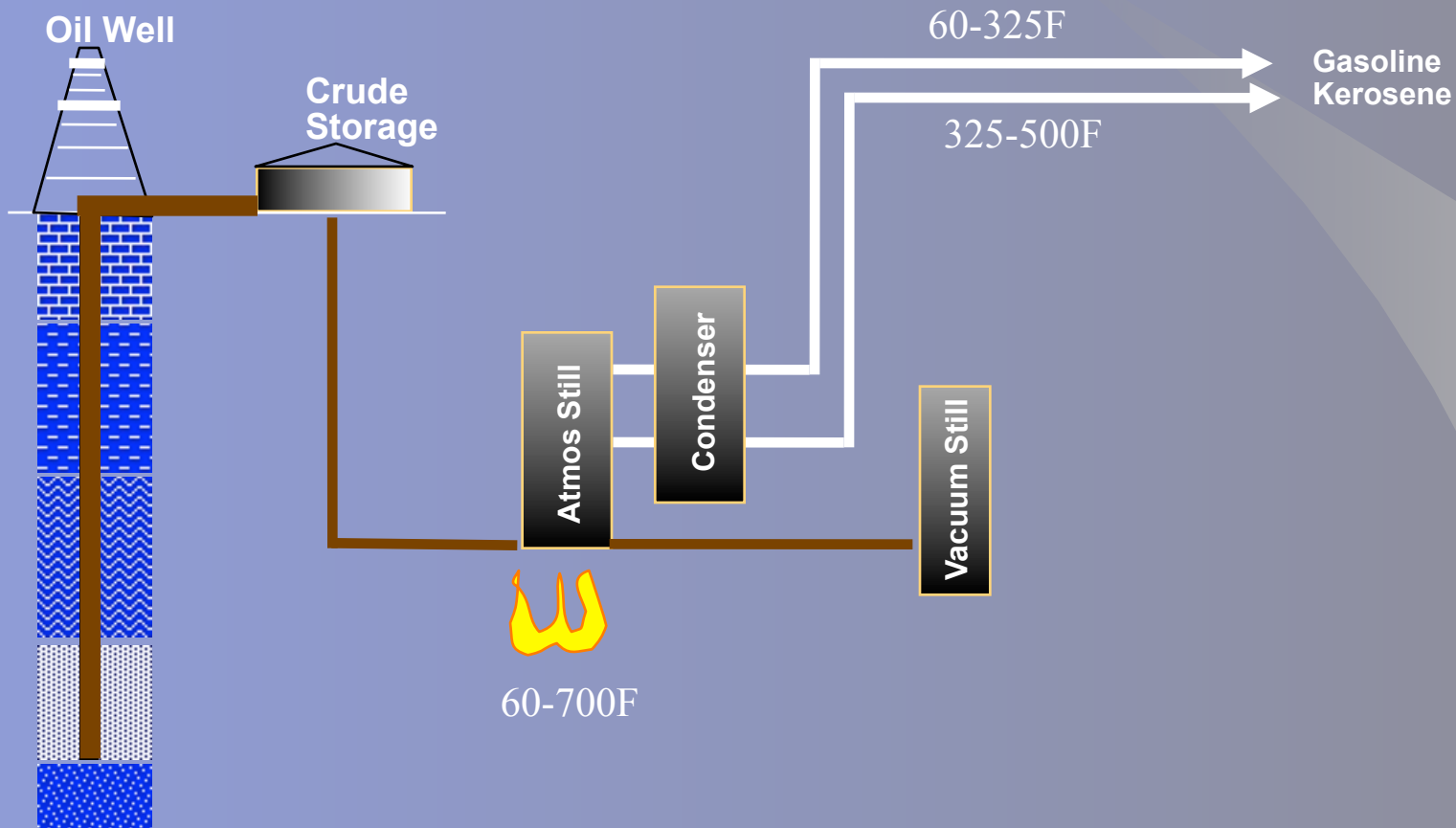
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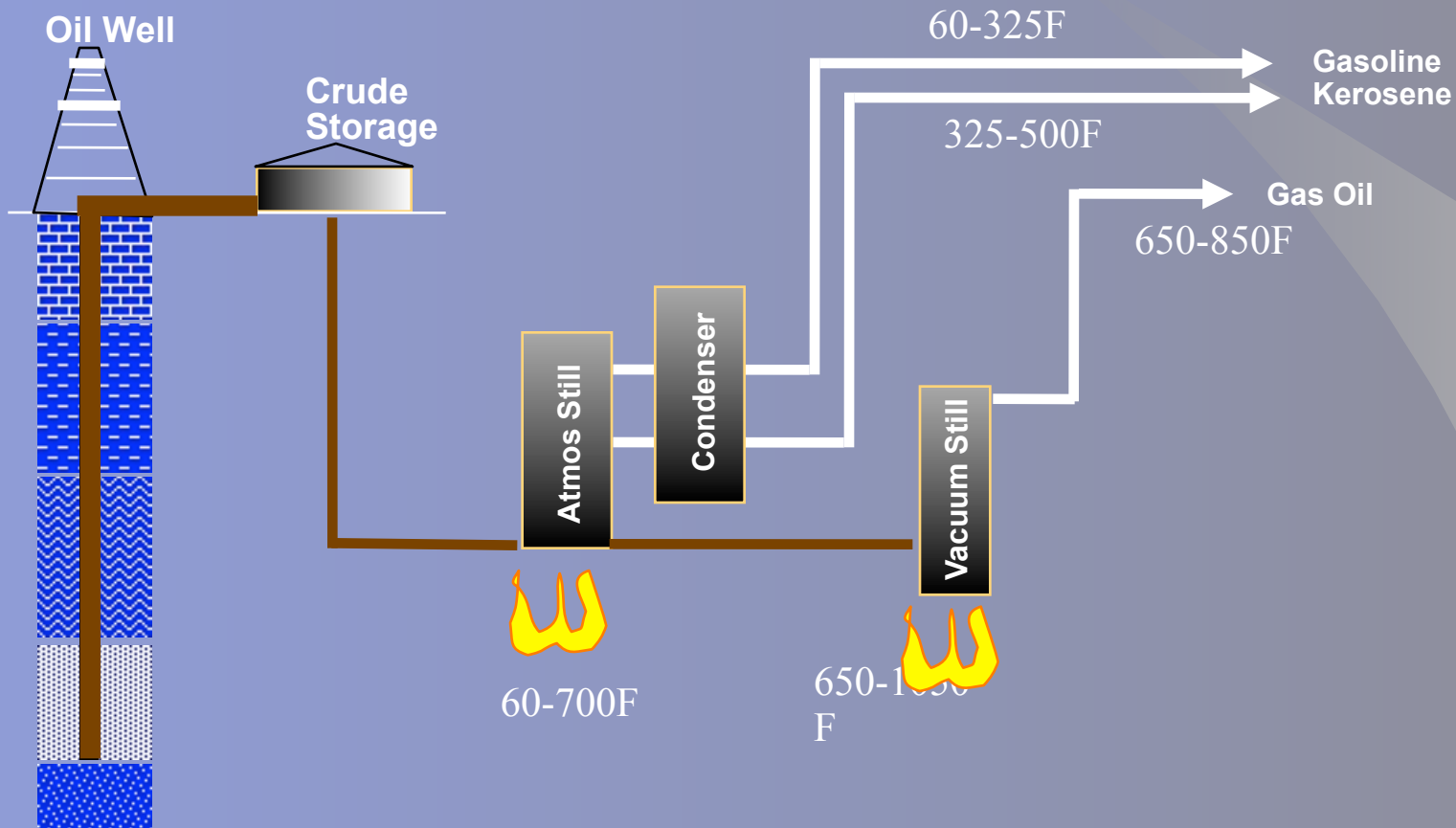
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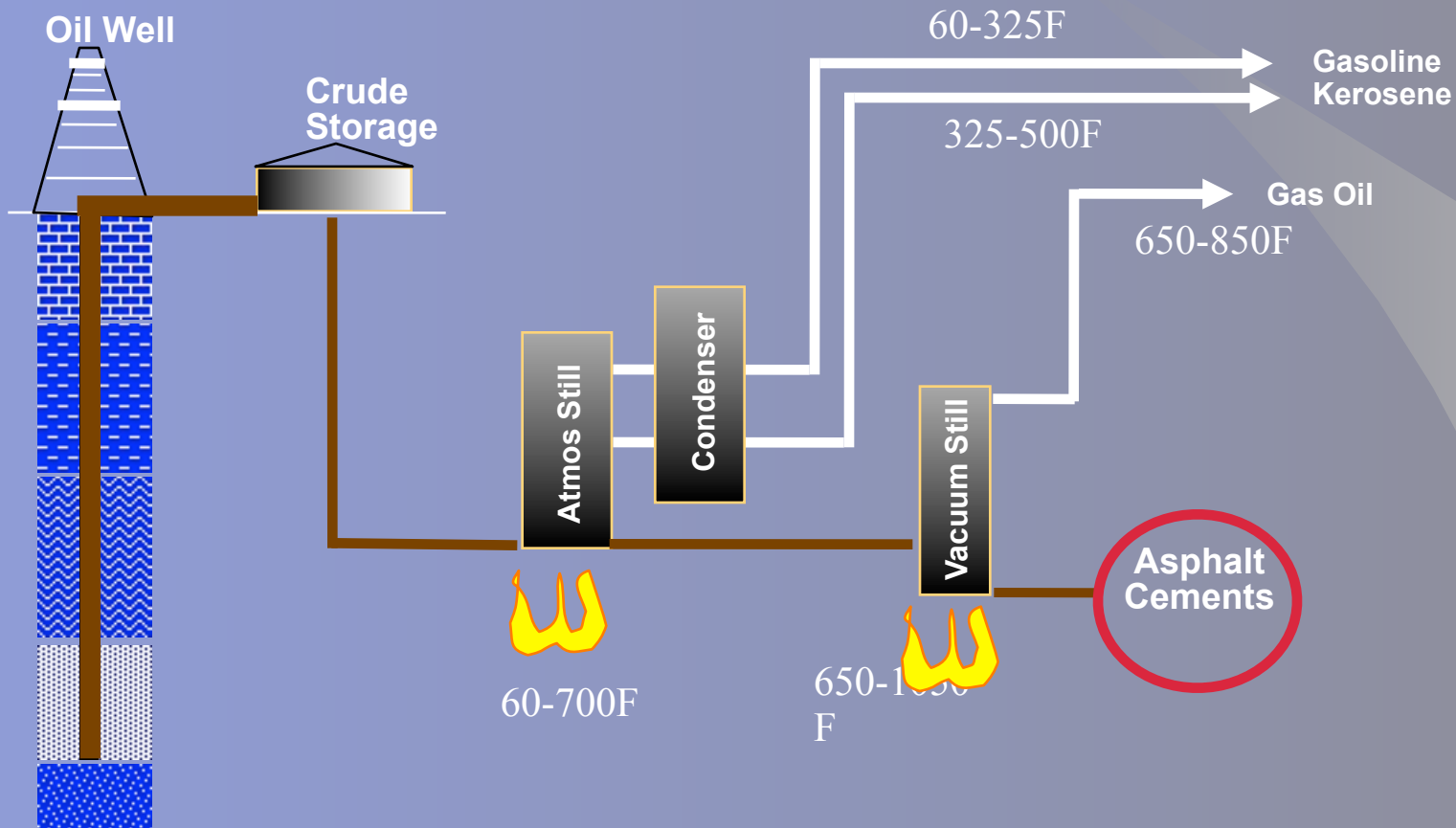
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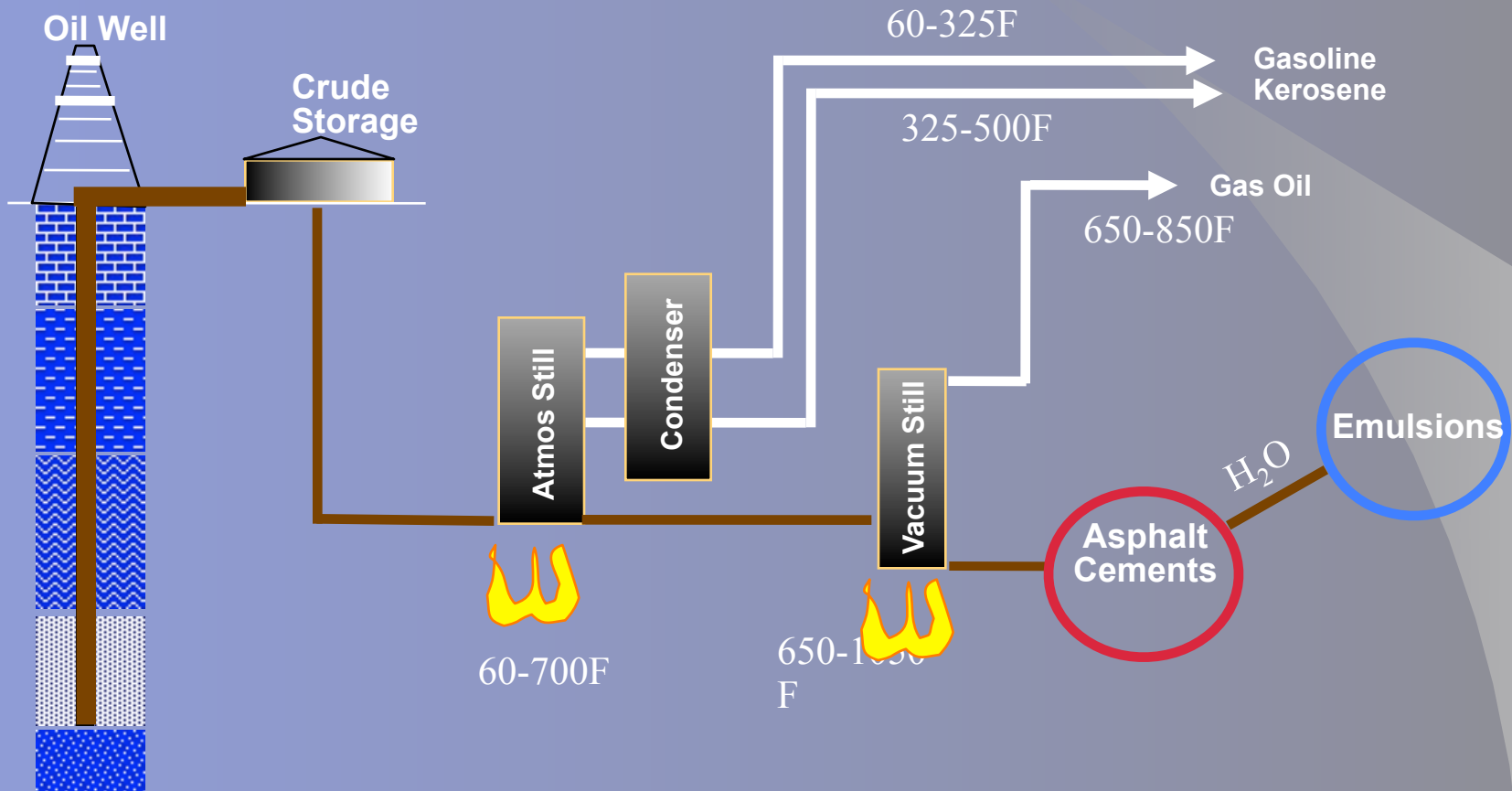
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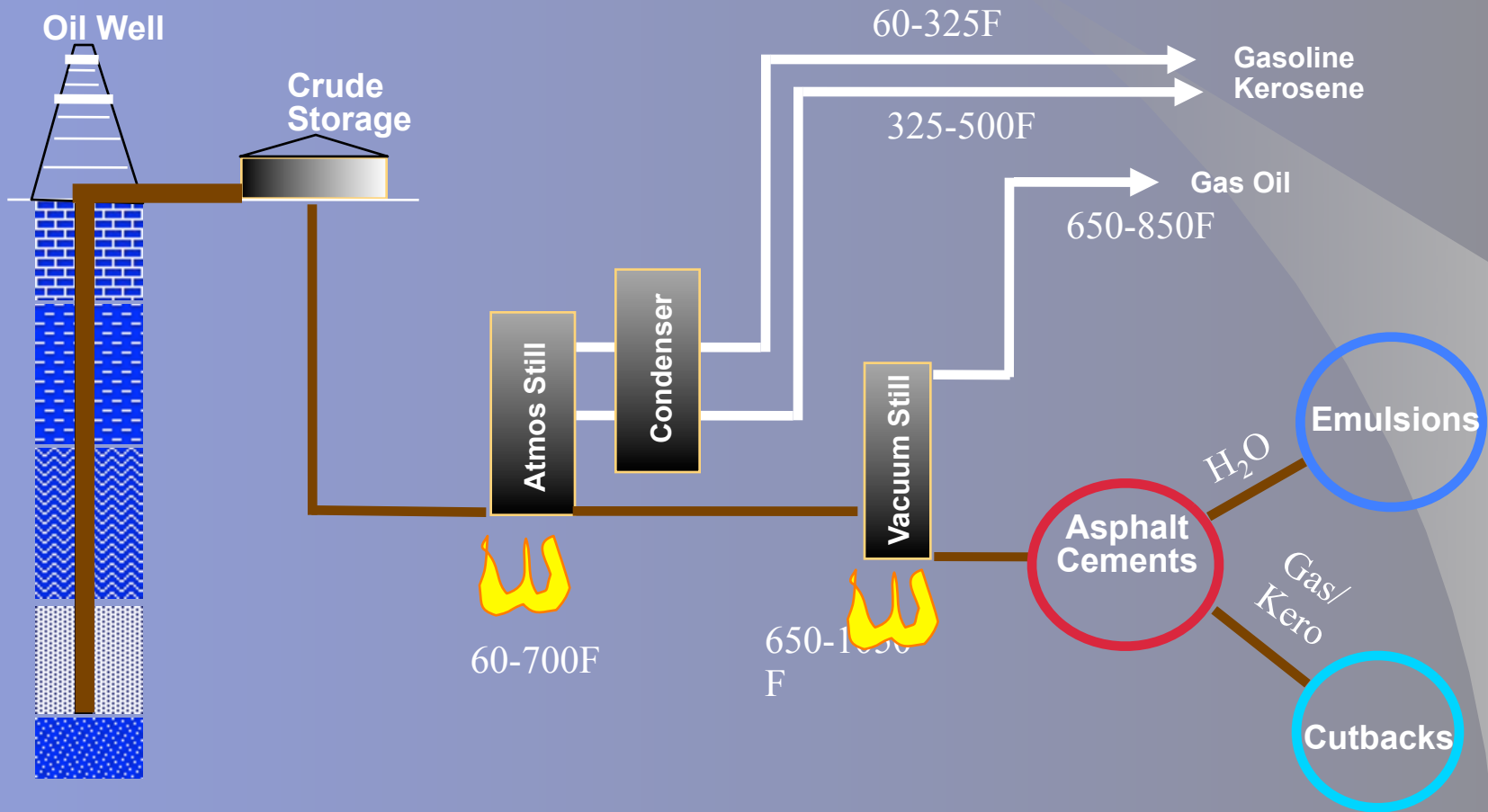
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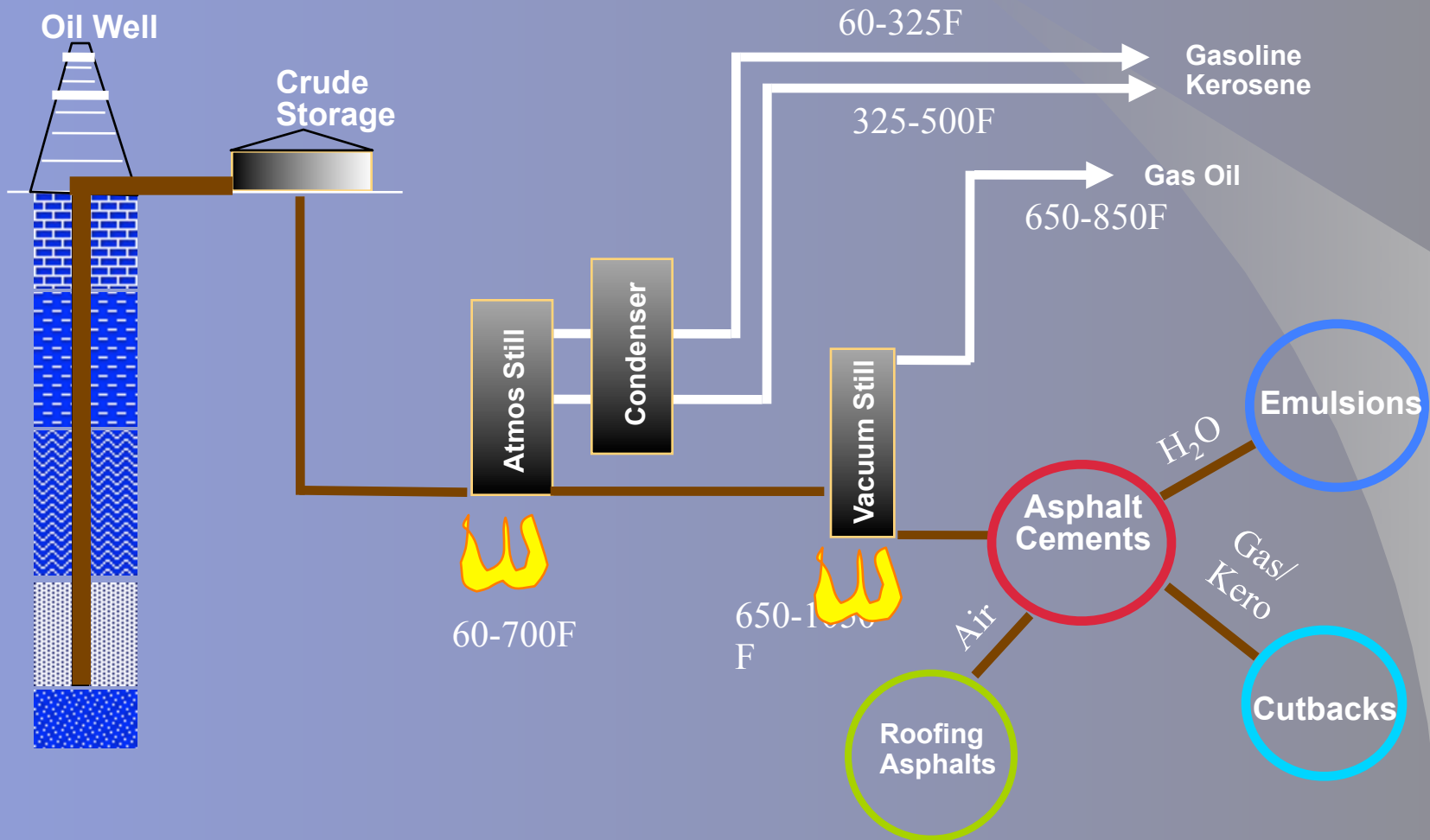
# Petroleum Asphalts



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# Asphalt Types

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- Asphalt Cement

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- Asphalt Cement
- Liquid Asphalts
  - Emulsified Asphalts
  - Cutback Asphalts

# Behavior of Asphalt Cements

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- Asphalt is Viscoelastic
  - Viscous (Flows) at High Temperatures

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- Silly Putty is Viscoelastic
  - Pull it Slowly- It stretches – same as high temperature

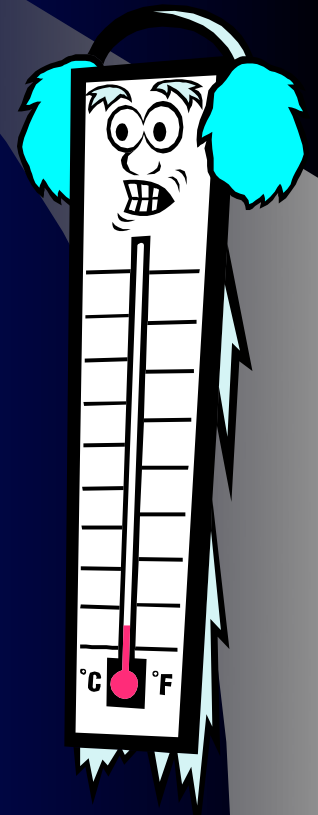
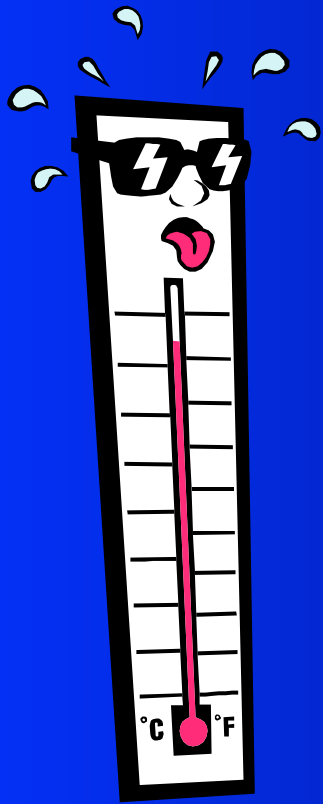
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- Silly Putty is Viscoelastic
  - Pull it Slowly- It stretches – same as high temperature
  - Pull it Rapidly – It breaks – same as low temperature



Asphalt Performance depends  
on Environment and Traffic

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# Hot Behavior



Hot Behavior



Weak Behavior



Hot Behavior



Weak Behavior



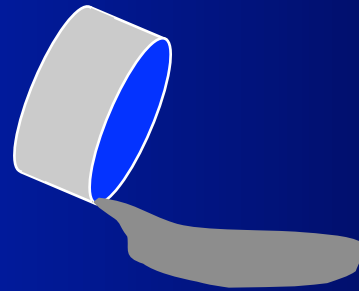
Cold Behavior

# Temperature Effects

# Temperature Effects

1 Hour

100°F

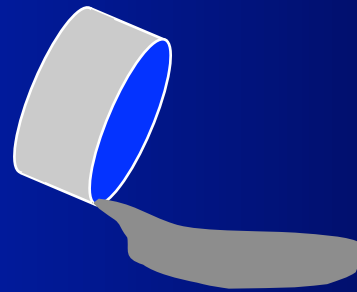




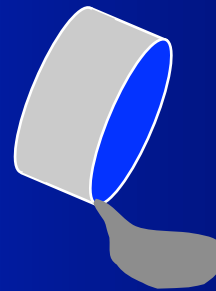
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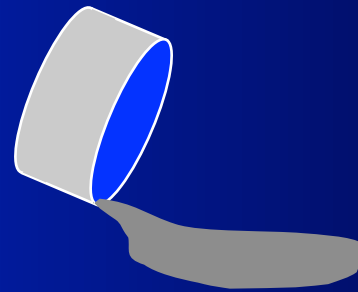
30°F



# Temperature Effects

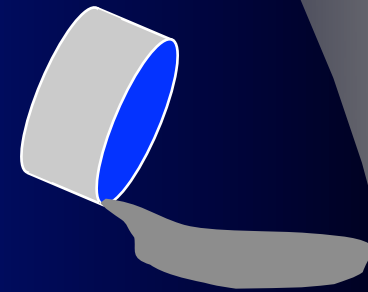
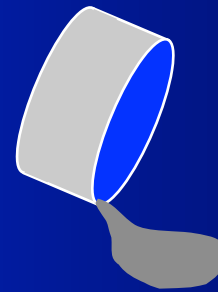
1 Hour

100°F

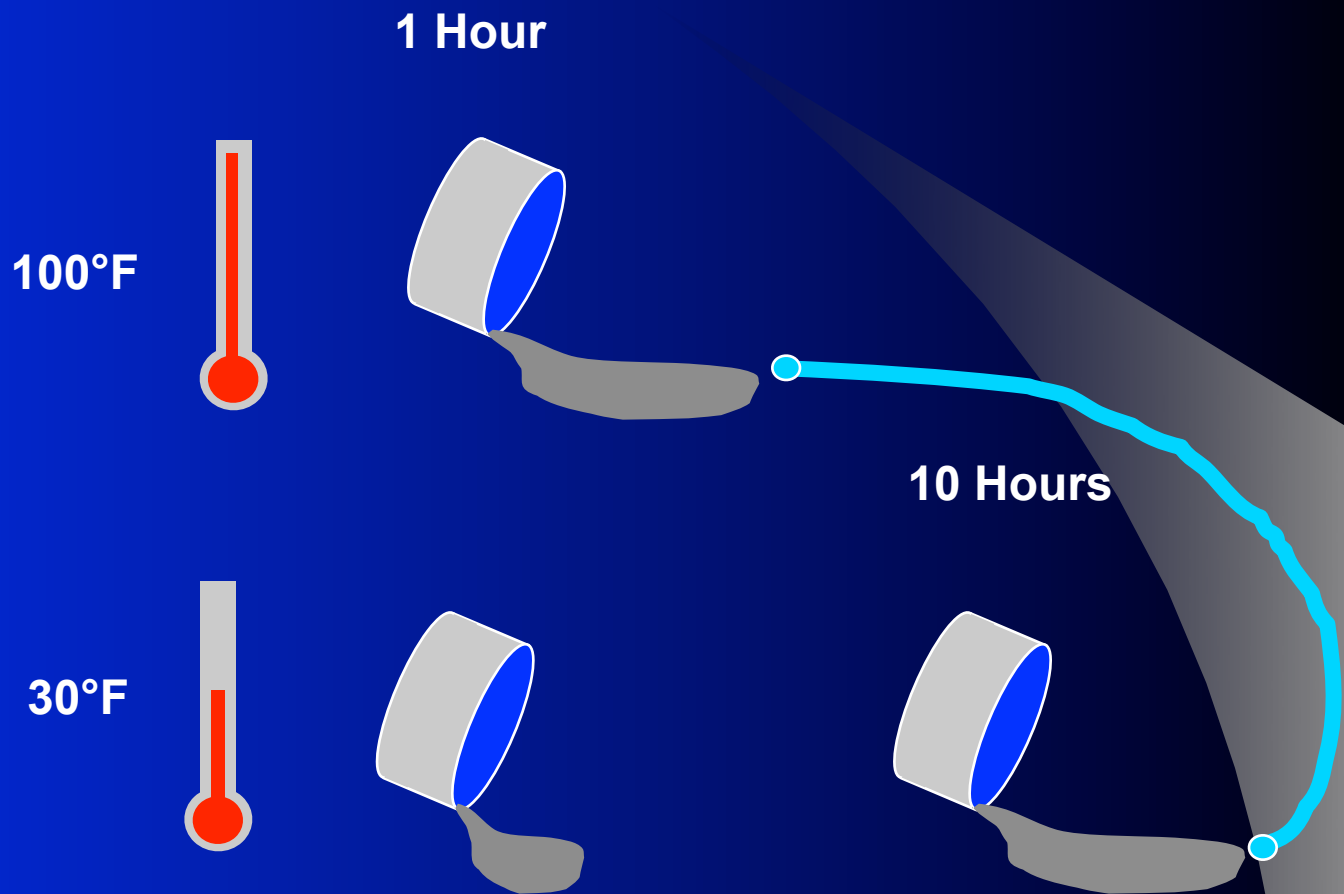


10 Hours

30°F



# Temperature Effects

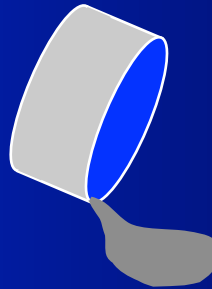


# Material Effects

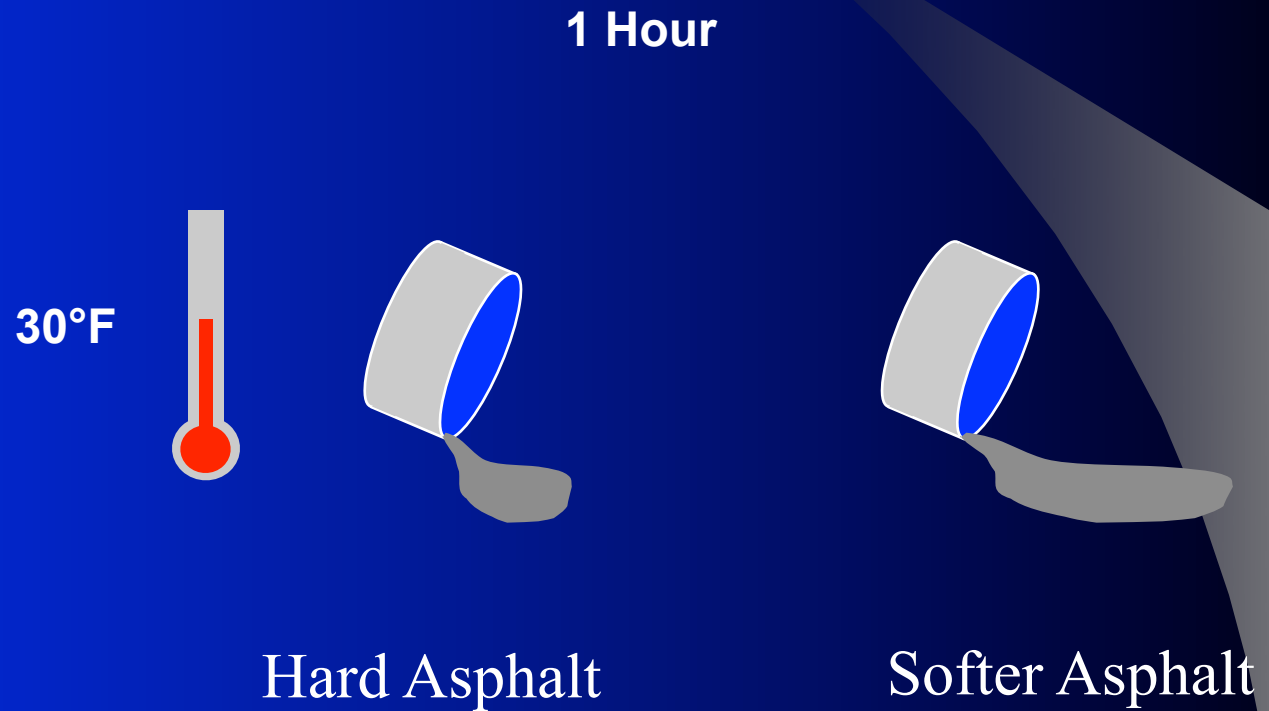
# Material Effects

1 Hour

30°F



# Material Effects





# Achieving



# SUPERPAVE

## To The Rescue !

# SUPERPAVE



To The Rescue !

# SPECIFYING PERFORMANCE

Based on Climate

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**PG 64 - 22**

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Performance  
Grade



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**PG 64 - 22**

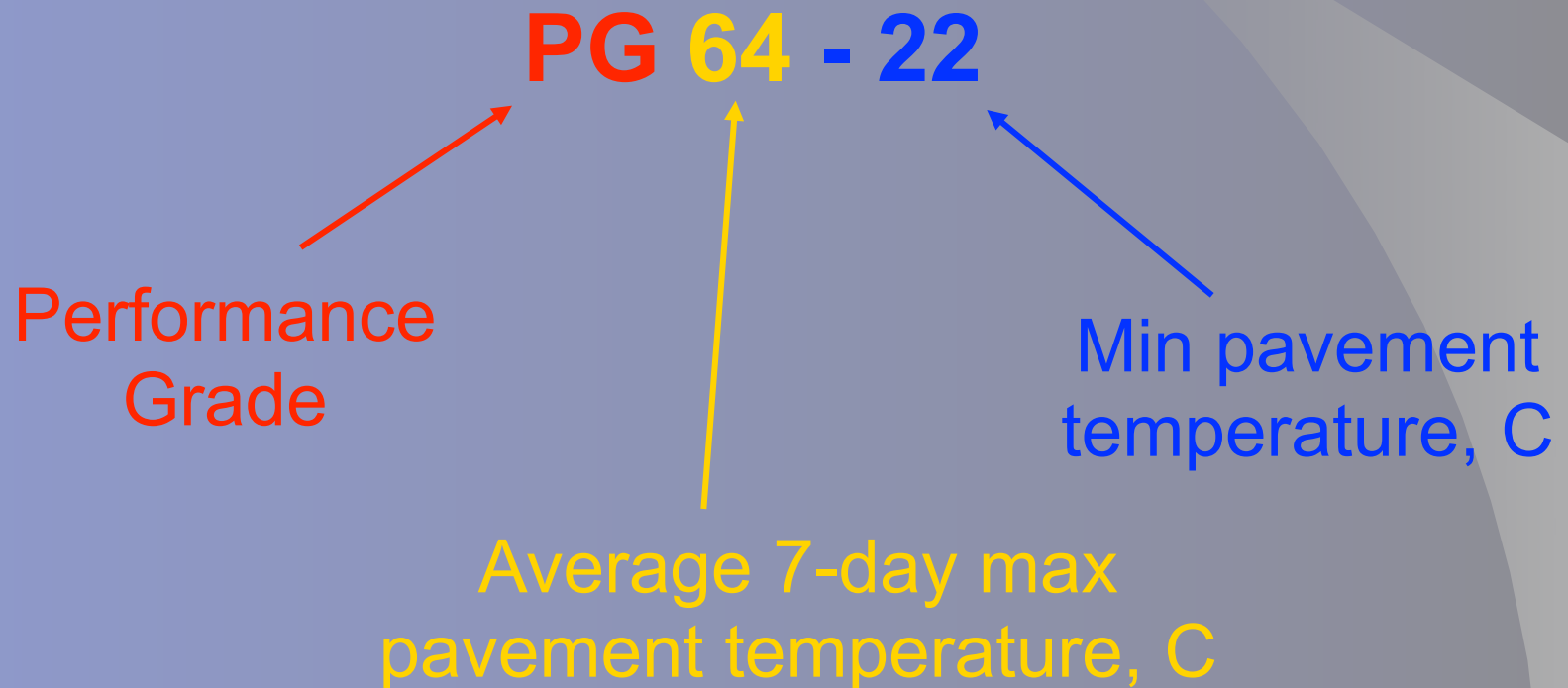
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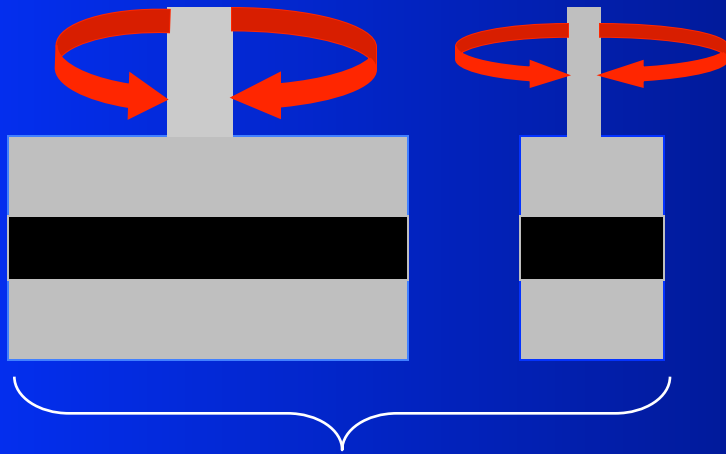
Average 7-day max  
pavement temperature, C

# SPECIFYING PERFORMANCE

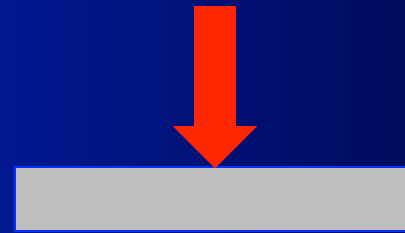
Based on Climate



# Tests in PG Specifications



**Dynamic  
Shear  
Rheometer**



**Bending  
Beam  
Rheometer**



**Rotational  
Viscometer**



# Permanent Deformation (Rutting)



Courtesy of FHWA

**Caused by Warm Weather, Traffic and Wrong Mixture**

# High Temperature or, Slow Loading Behavior, aka Rutting

- High Pavement Temperature
  - Desert climates
  - Summer temperatures
- Sustained loads
  - Slow moving trucks
  - Intersections

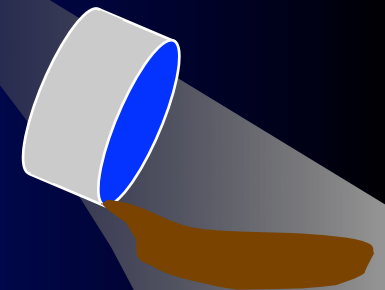
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  - Slow moving trucks
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100°F



1 Hour



# Thermal Cracking



Courtesy of FHWA

**Caused by Low Temperatures, Rapid Loads, Hard Binder**

# Low Temperature, or Fast Loading Behavior-aka Cracking

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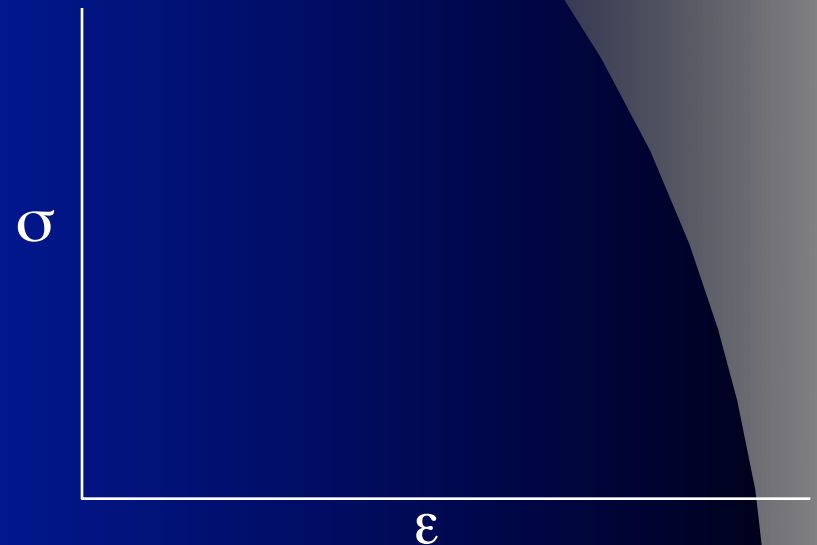
- Low Temperature
  - Cold climates
  - Winter

# Low Temperature, or Fast Loading Behavior-aka Cracking

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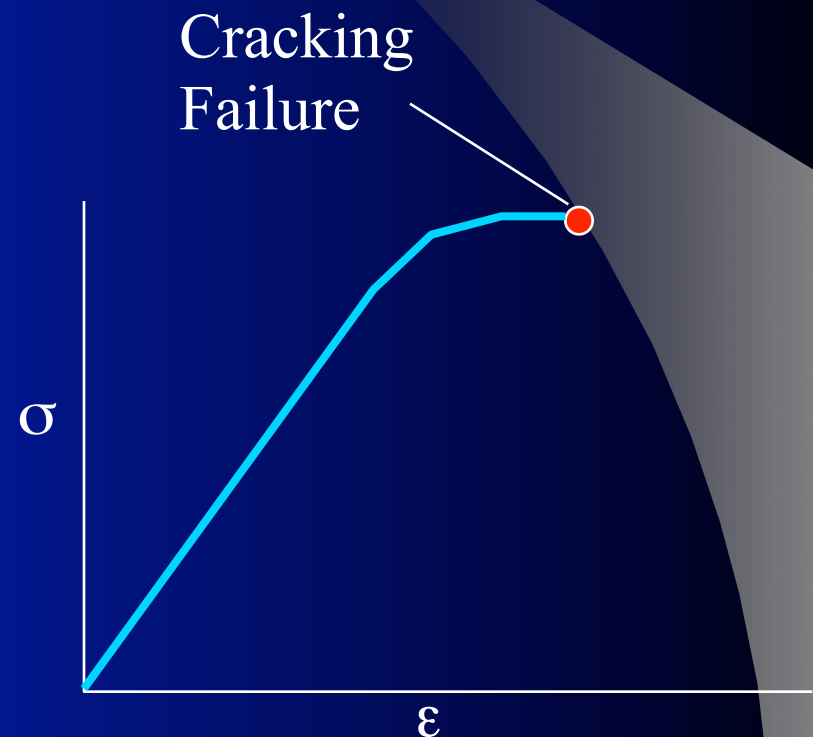
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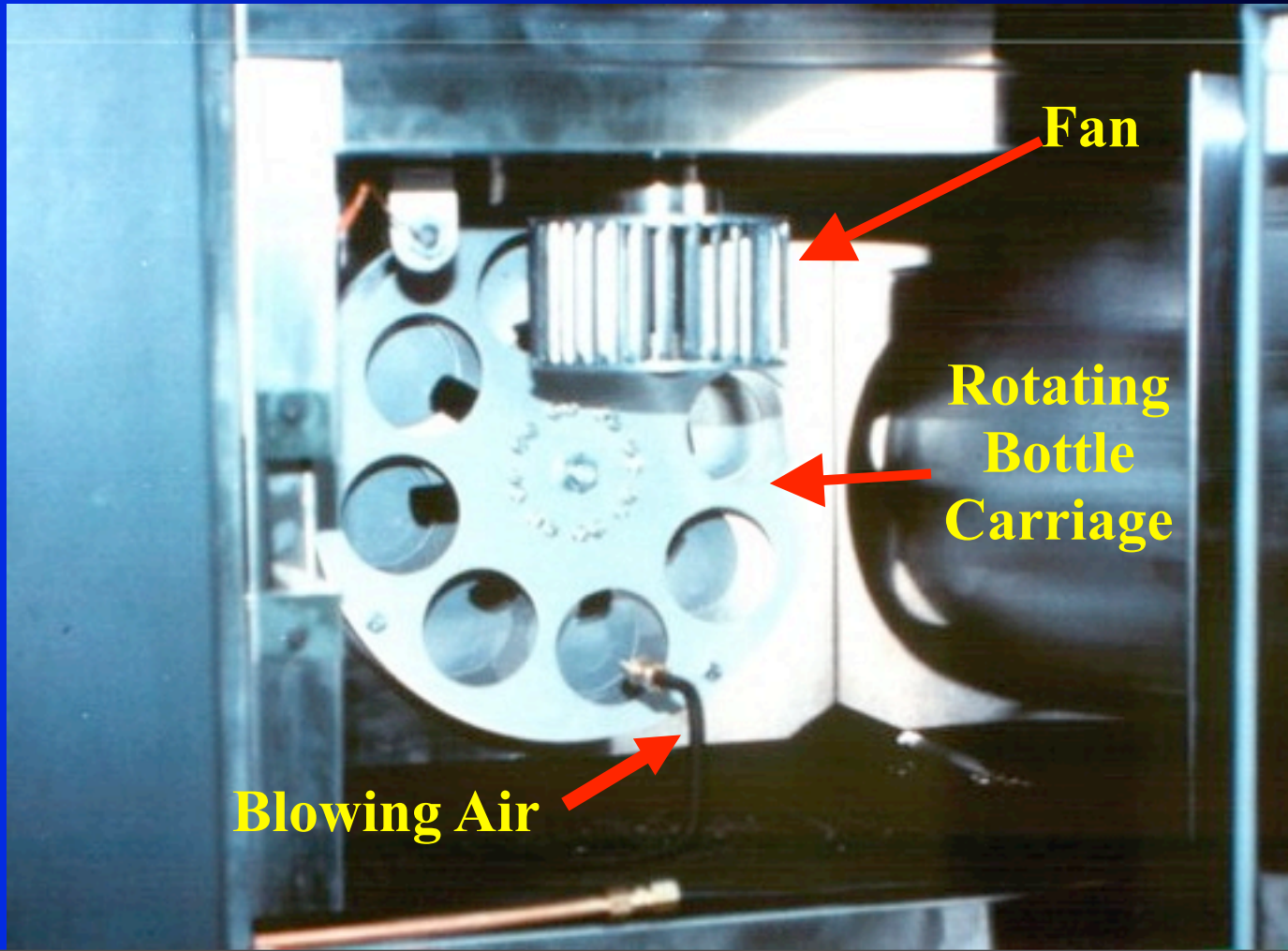


# Aging

- Asphalt reacts with oxygen
  - Becomes harder, more brittle
  - More Elastic, Less Viscous
- Short term
  - During Mixing with Aggregates (280F-330F)
- Long term
  - In Pavement
  - Air, Water, Sun

# Asphalt Plant and Construction Aging

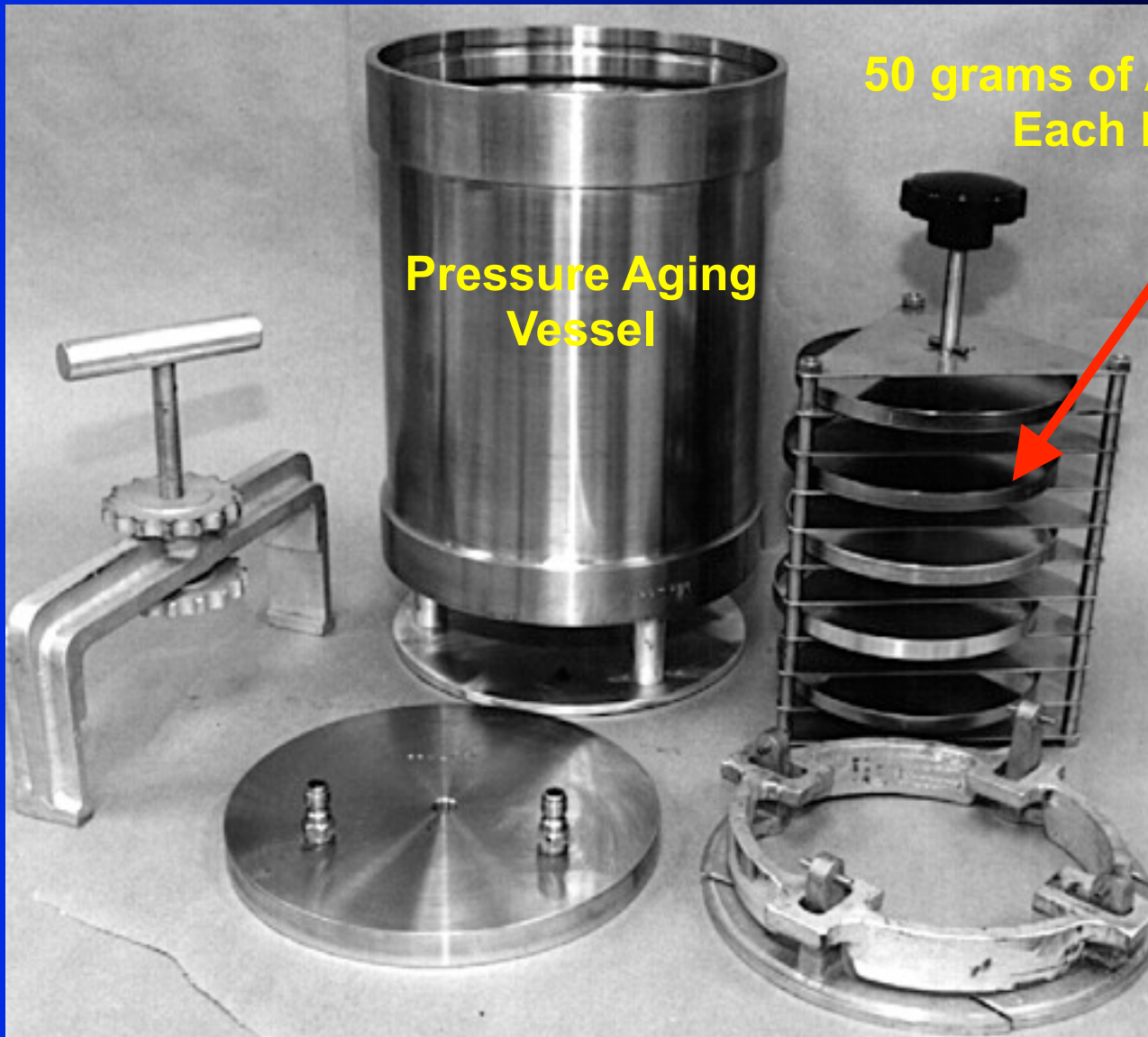
- Rolling Thin Film Oven (RTFO)



# Pressure Aging Vessel



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Pressure Aging  
Vessel

50 grams of Asphalt in  
Each Pan



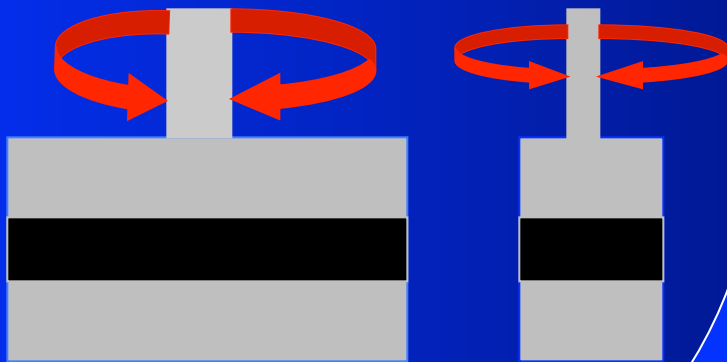
# Pressure Aging Vessel



Courtesy of FHWA

# Rutting, Hardening and Fatigue

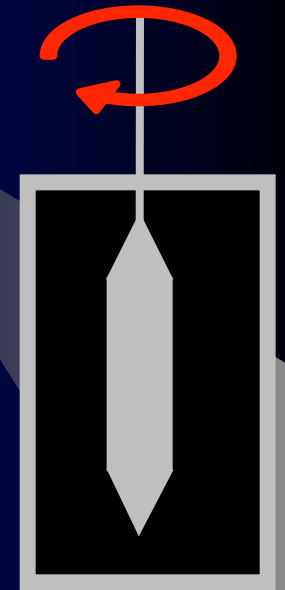
**DSR**



**BBR**



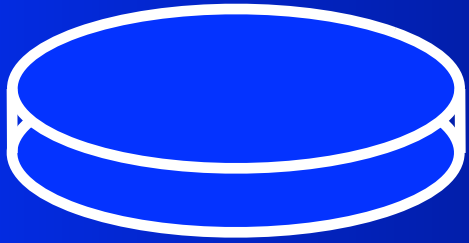
**RV**





1 cycle

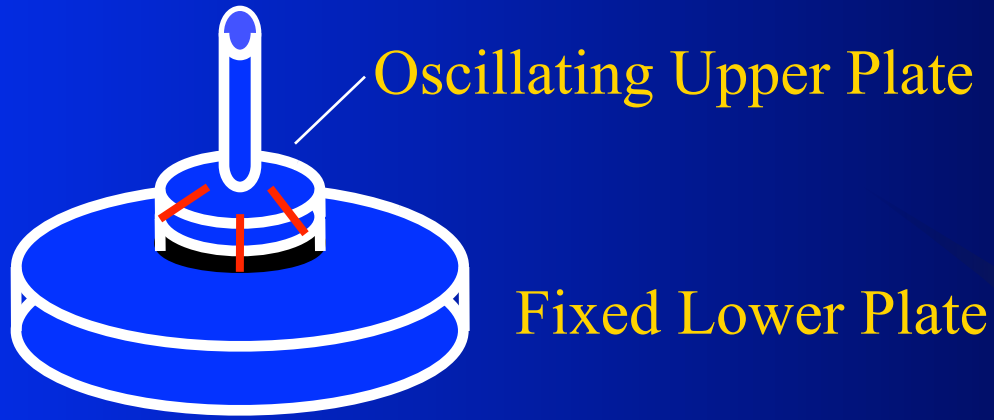




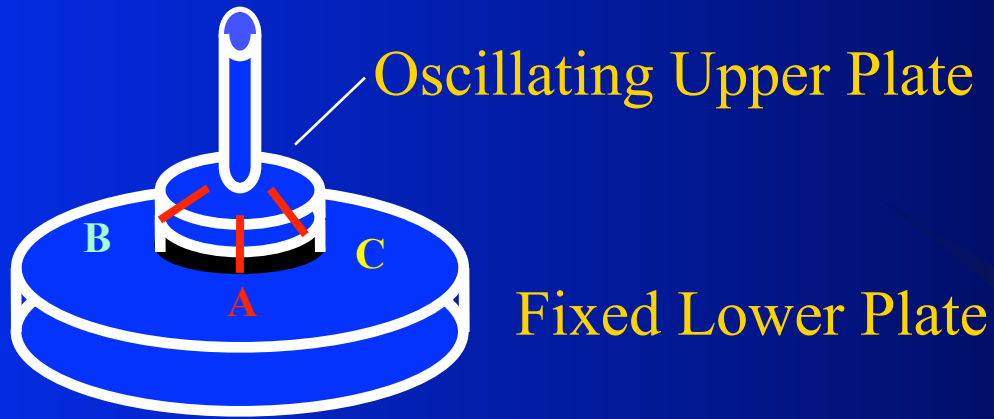
Fixed Lower Plate



1 cycle

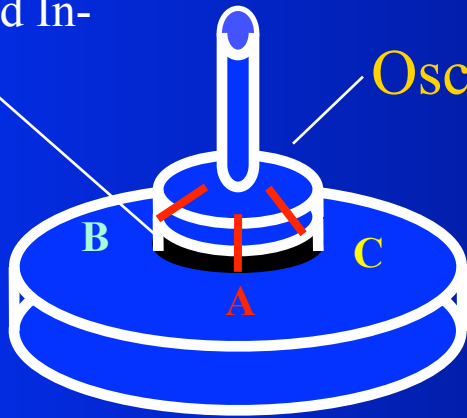


1 cycle



1 cycle

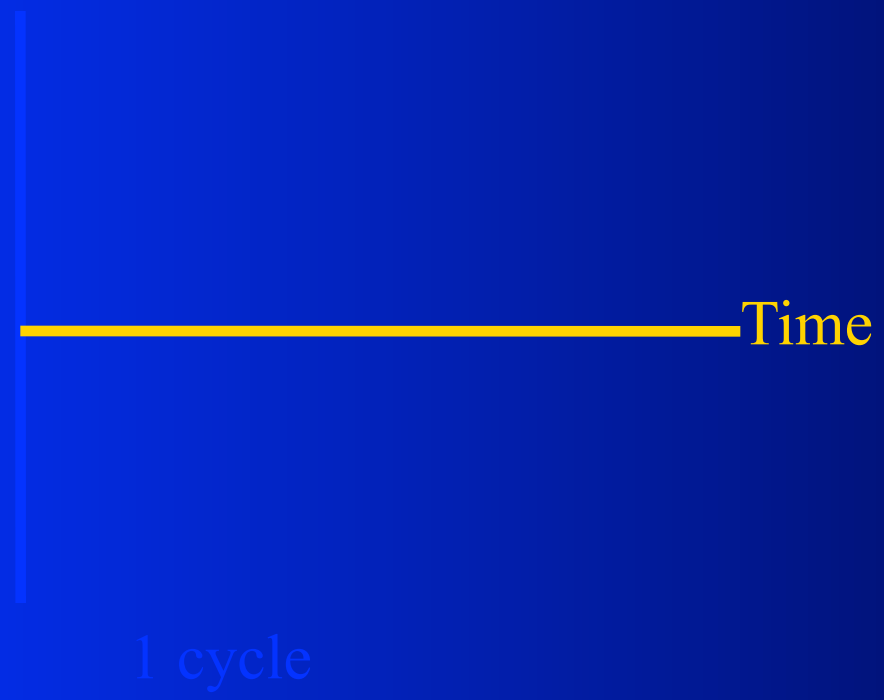
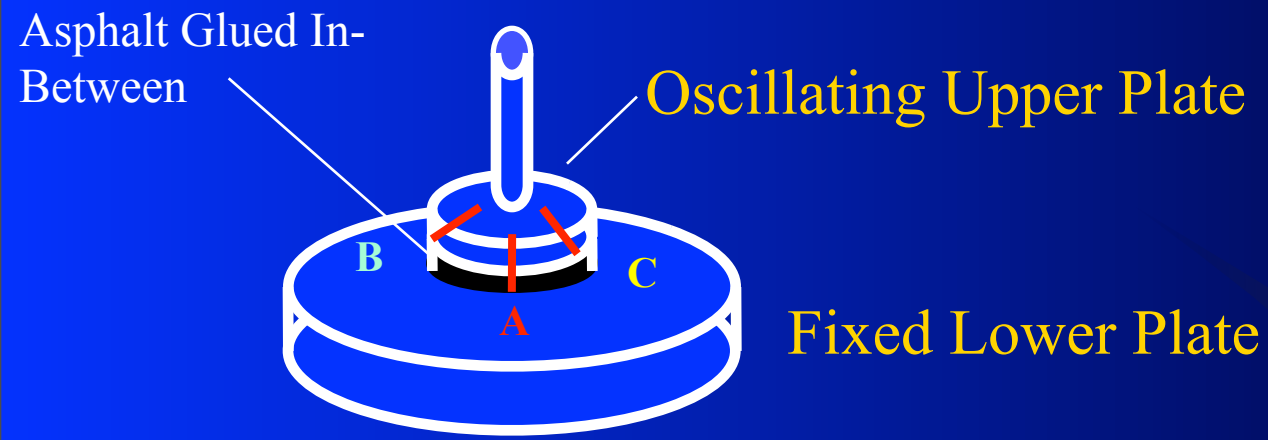
Asphalt Glued In-Between



Oscillating Upper Plate

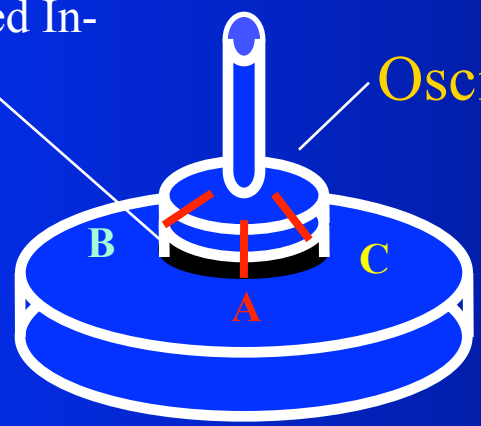
Fixed Lower Plate

1 cycle

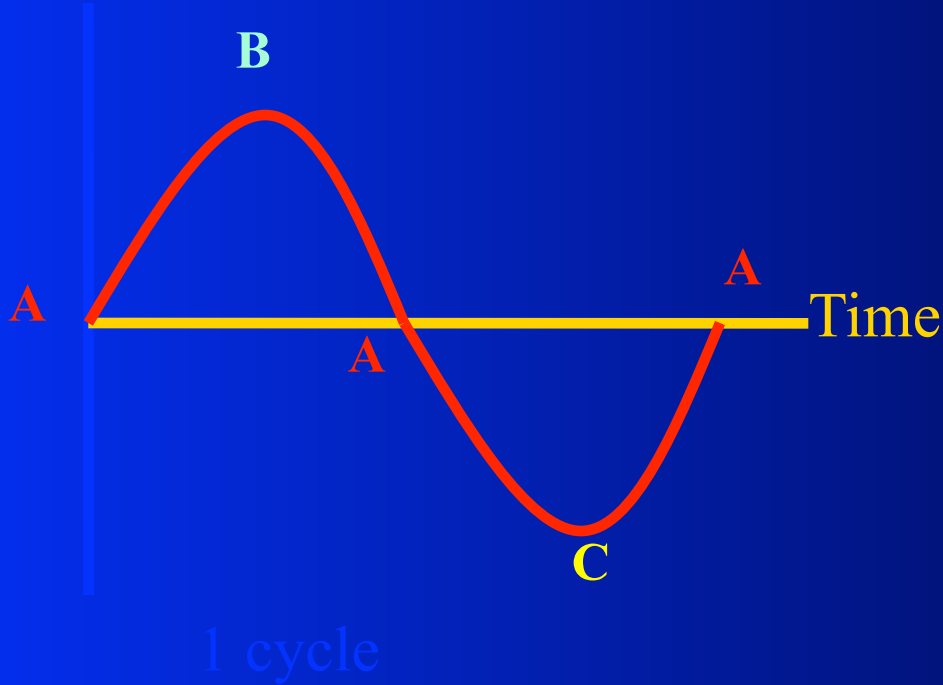


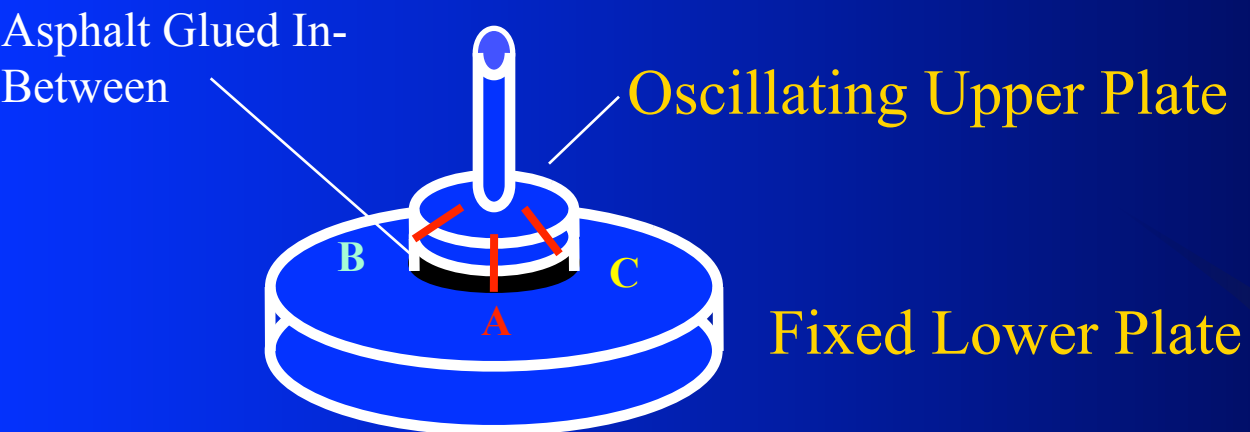
Asphalt Glued In-Between

Oscillating Upper Plate



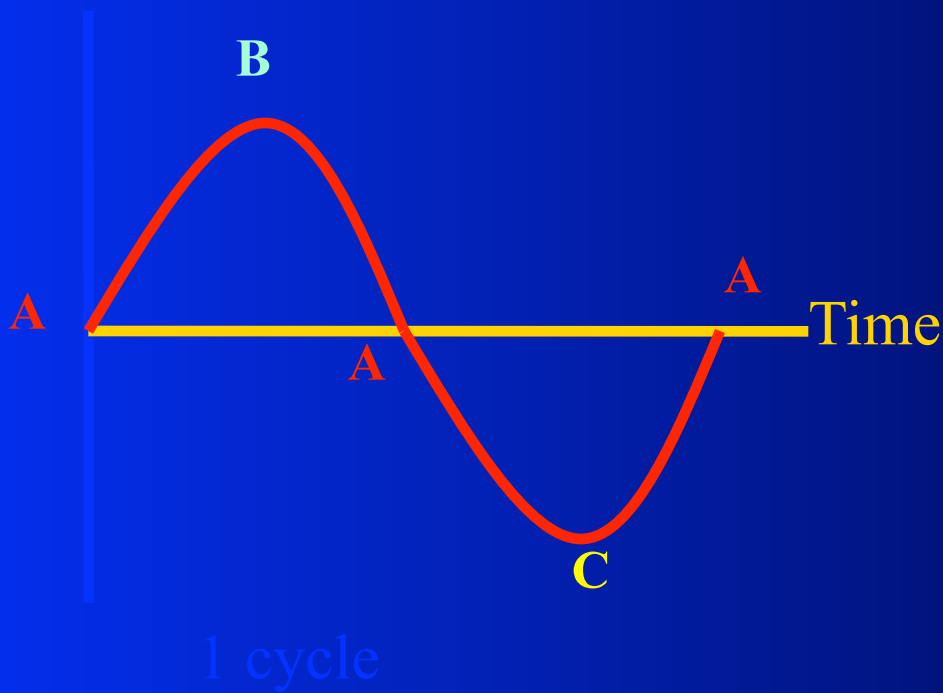
Fixed Lower Plate





Now, Measure the Force Required to Rotate the Upper Plate

And, Measure When Movement Occurs in the Binder



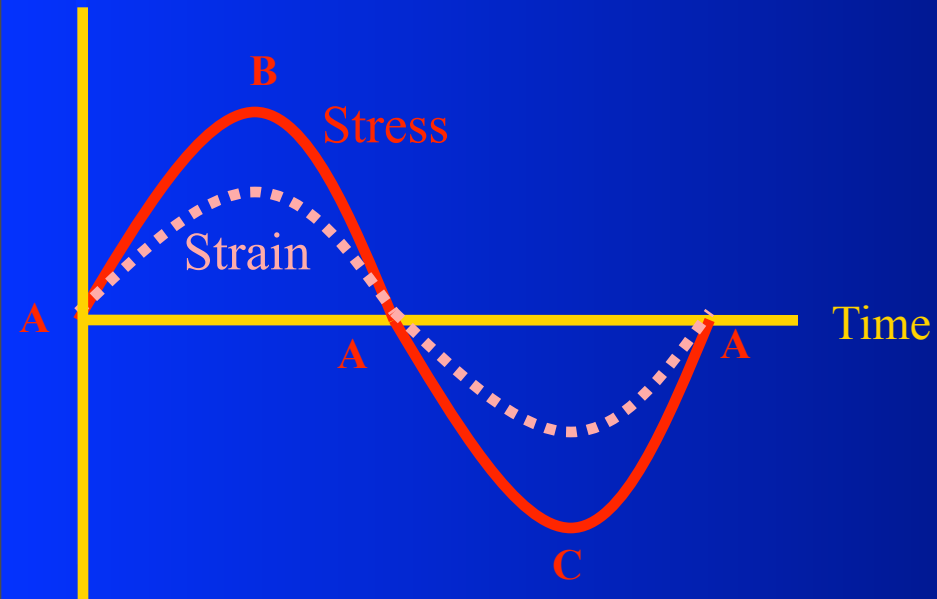




# Elastic



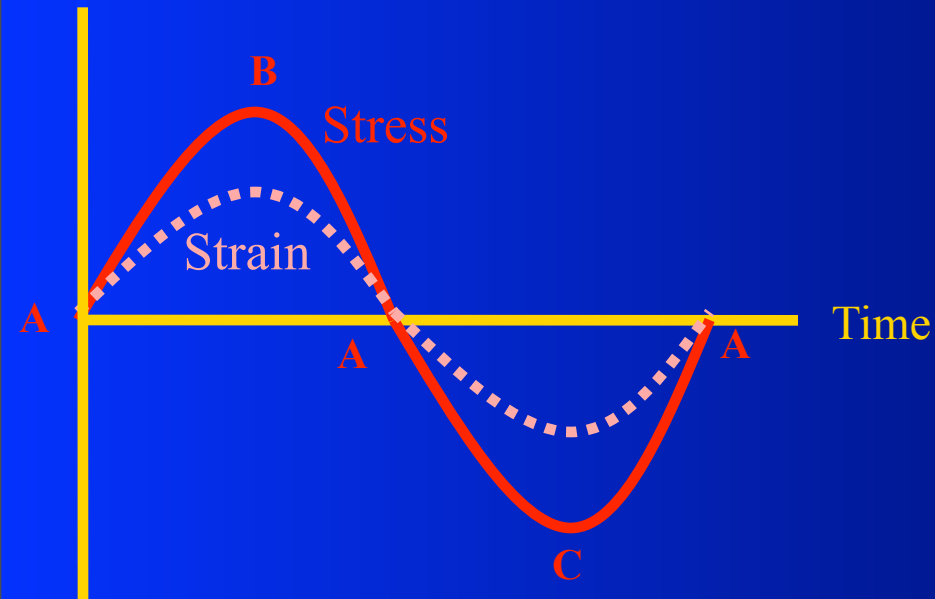
# Elastic



Strain Occurs With **Stress**  
 $\delta = 0^\circ$

# Elastic

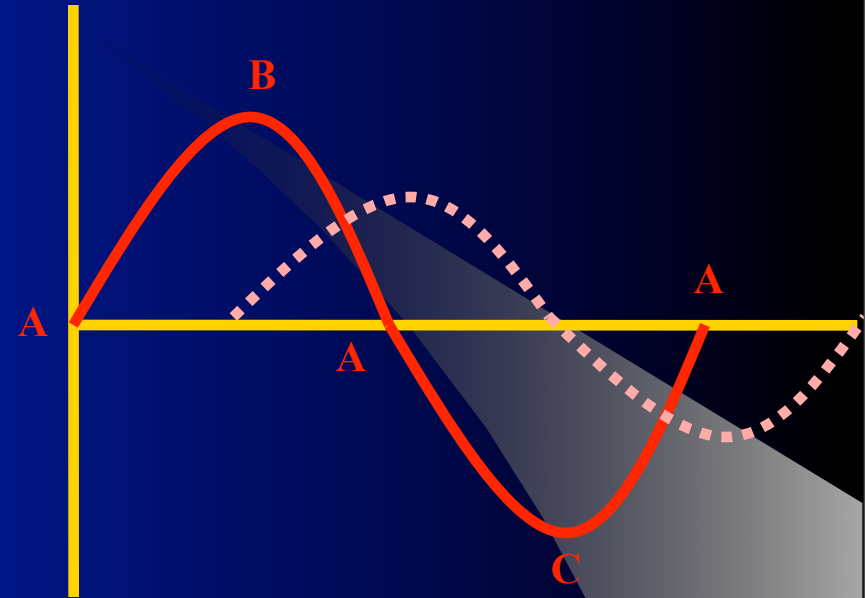
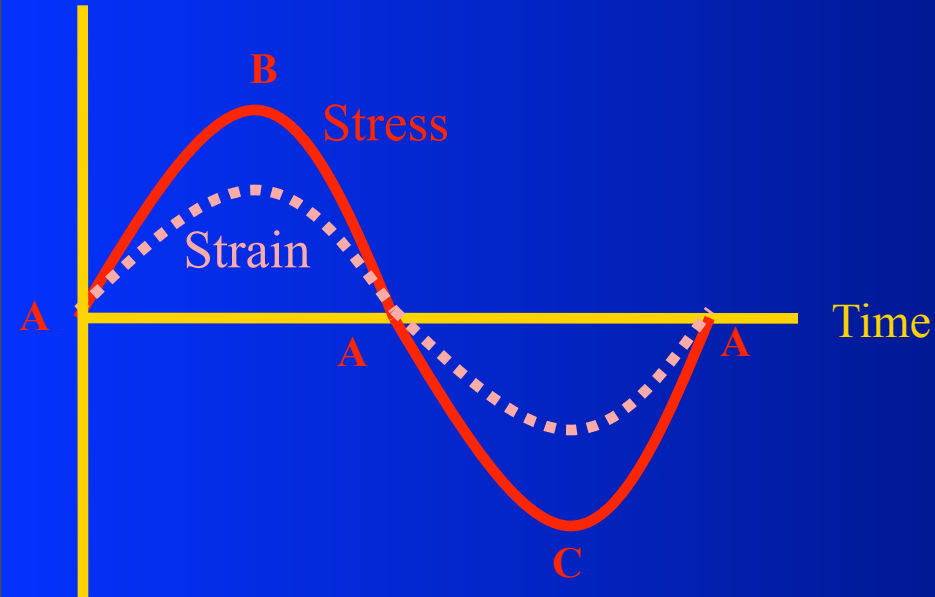
# Viscous



Strain Occurs With **Stress**  
 $\delta = 0^\circ$

# Elastic

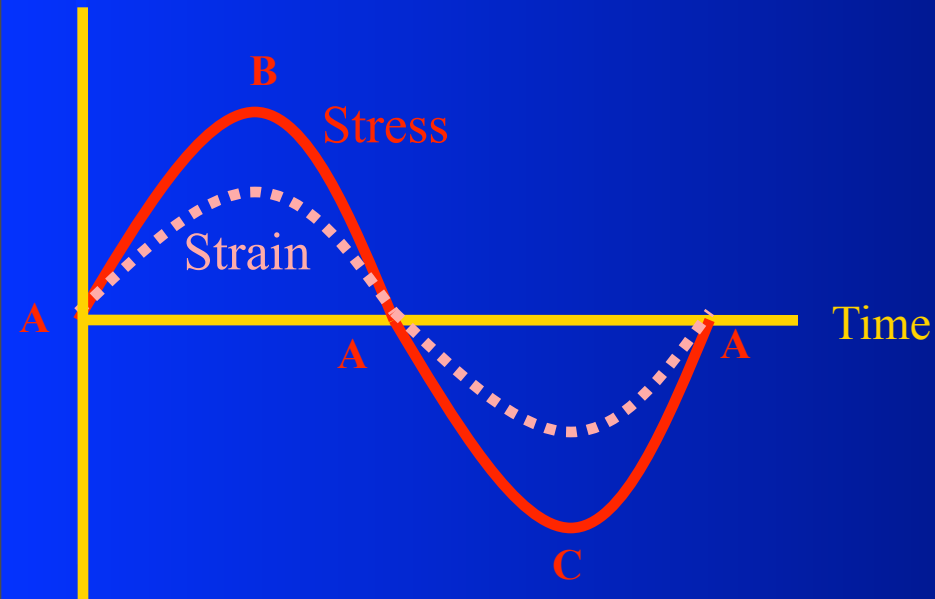
# Viscous



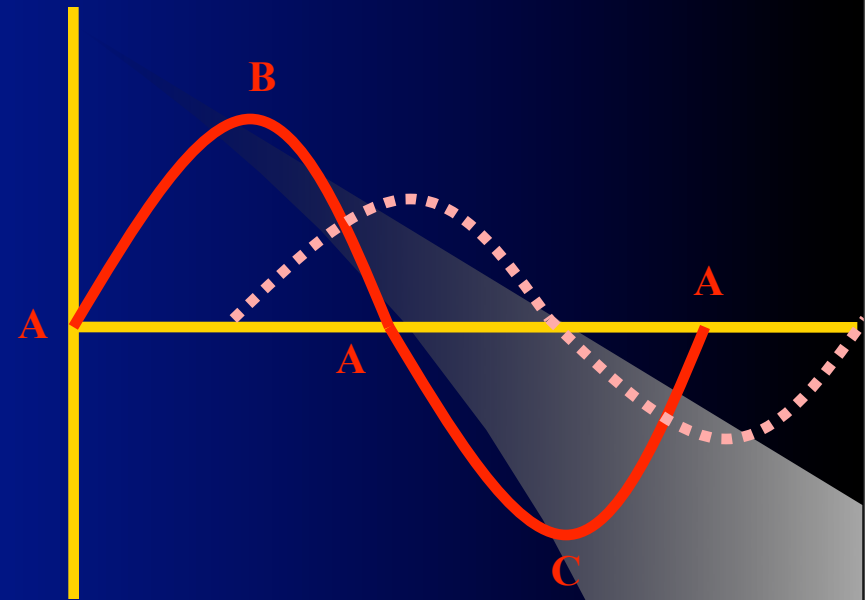
Strain Occurs With **Stress**  
 $\delta = 0^\circ$

# Elastic

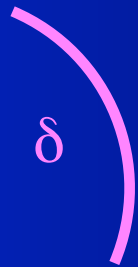
# Viscous



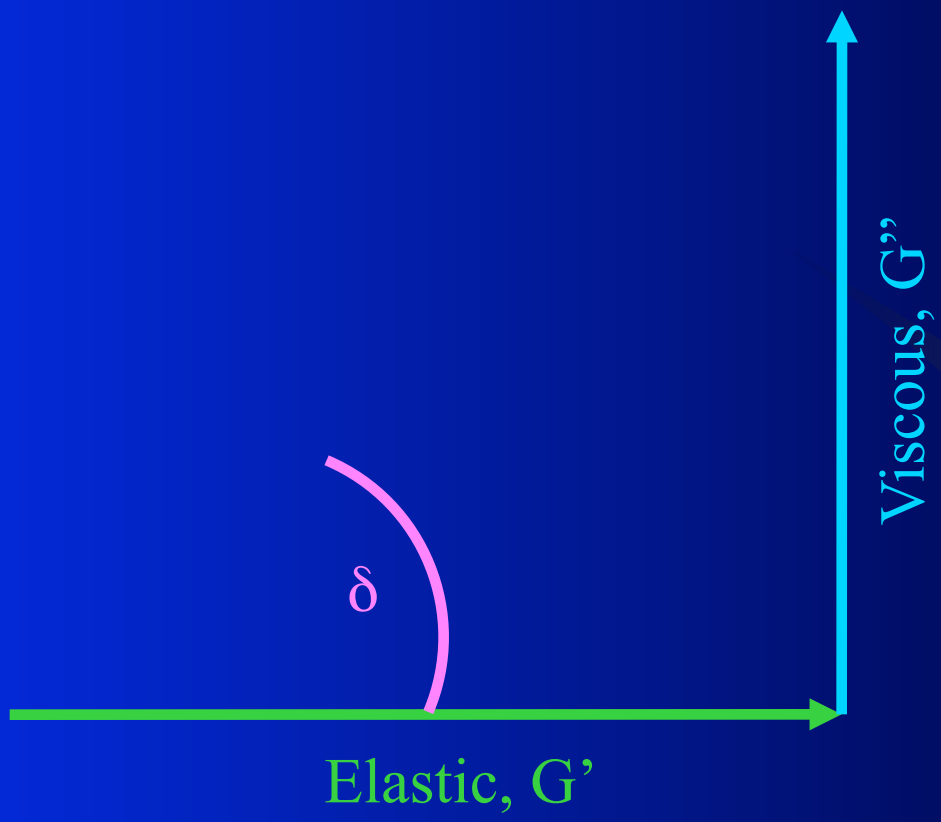
Strain Occurs With **Stress**  
 $\delta = 0^\circ$



Strain Lags **Stress**  
 $\delta = 90^\circ$





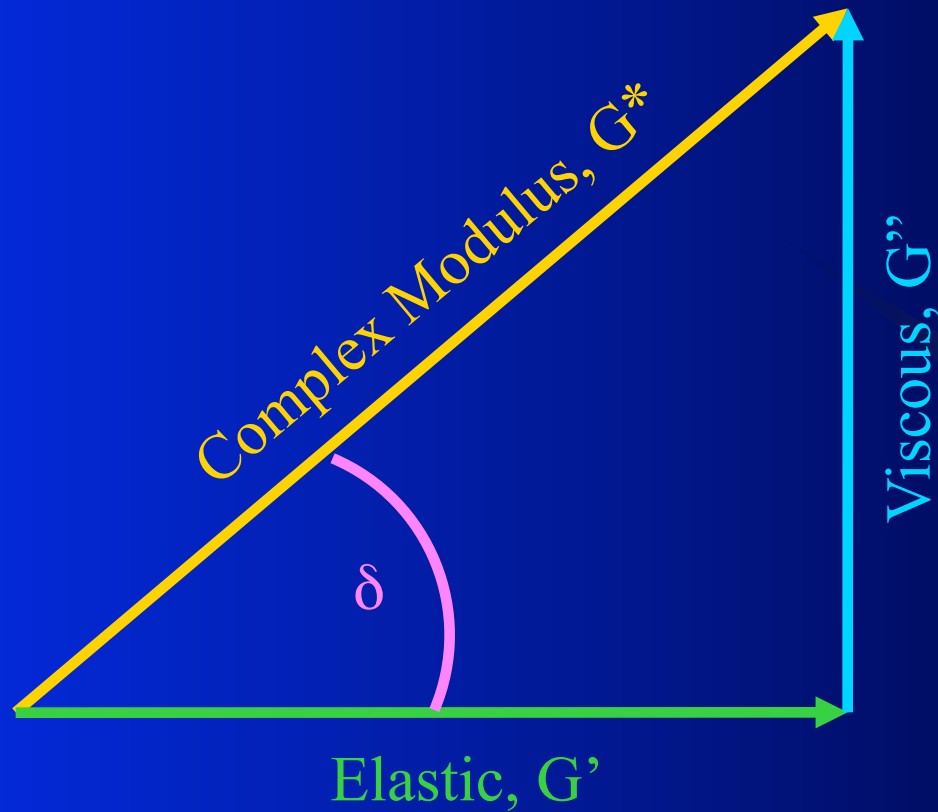


Viscous,  $G''$

Elastic,  $G'$

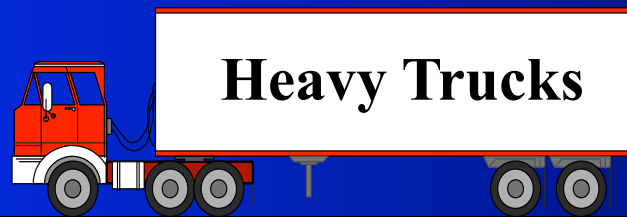
$\delta$





**Complex Modulus is  
the vector sum of  
Elastic and Viscous Components**

# Controlling Rutting



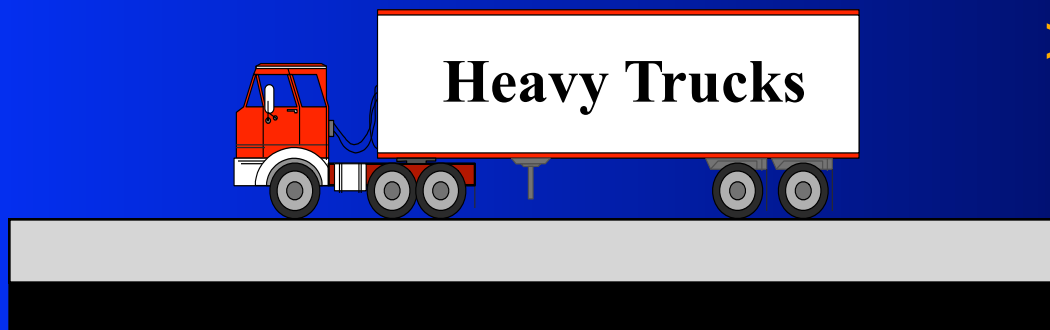
> *Early part of  
pavement life*

# Controlling Rutting

Addressed by:

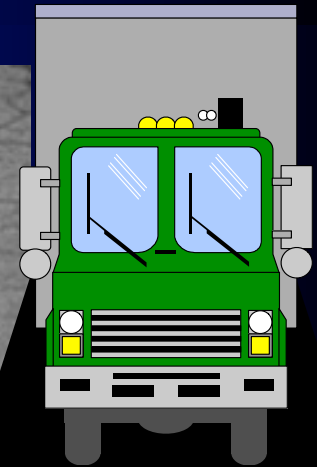
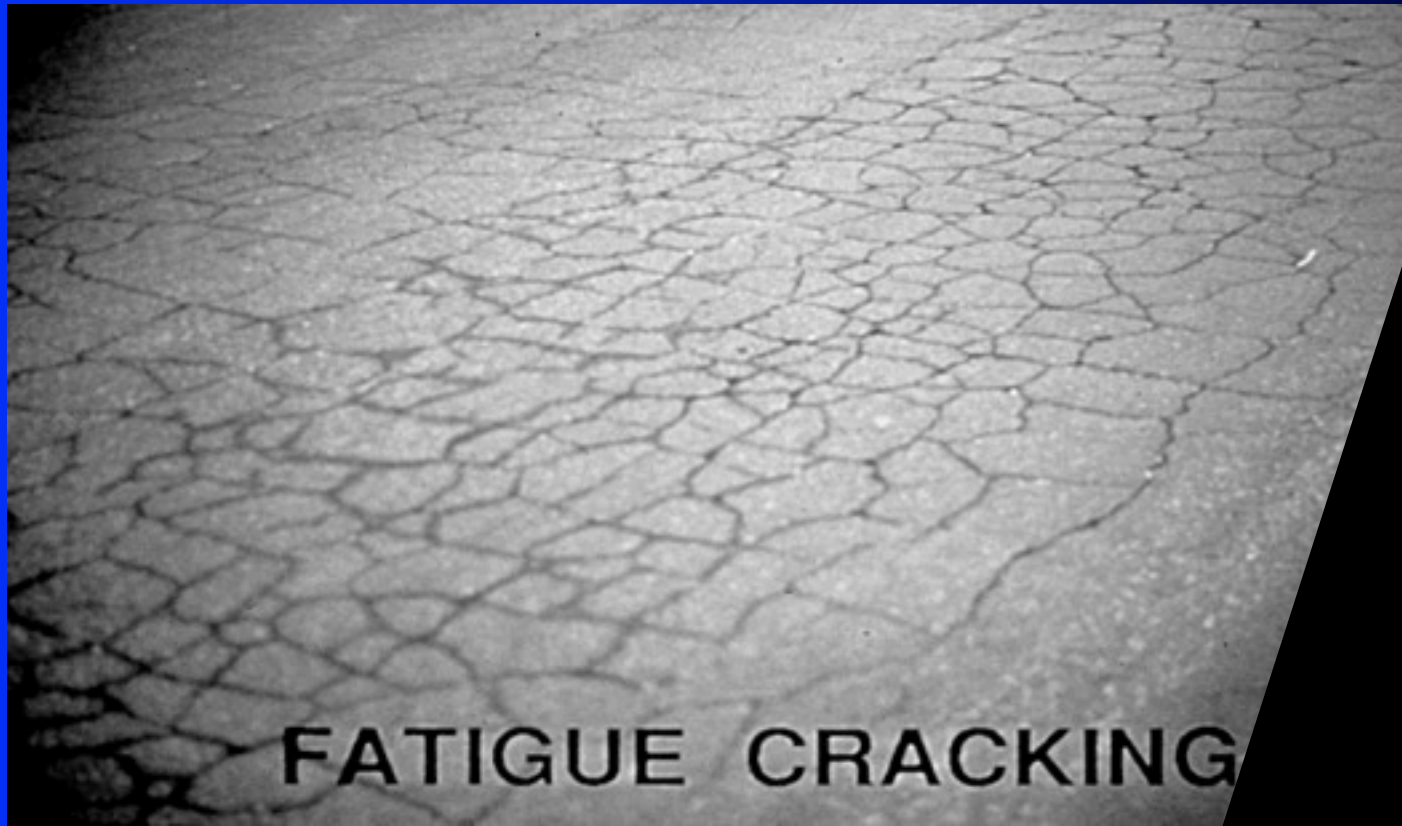
$G^*/\sin \delta$  on Unaged binder  $> 1.00$  kPa

$G^*/\sin \delta$  on Lab Aged binder  $\geq 2.20$  kPa

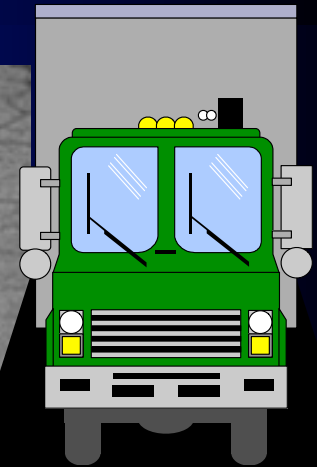
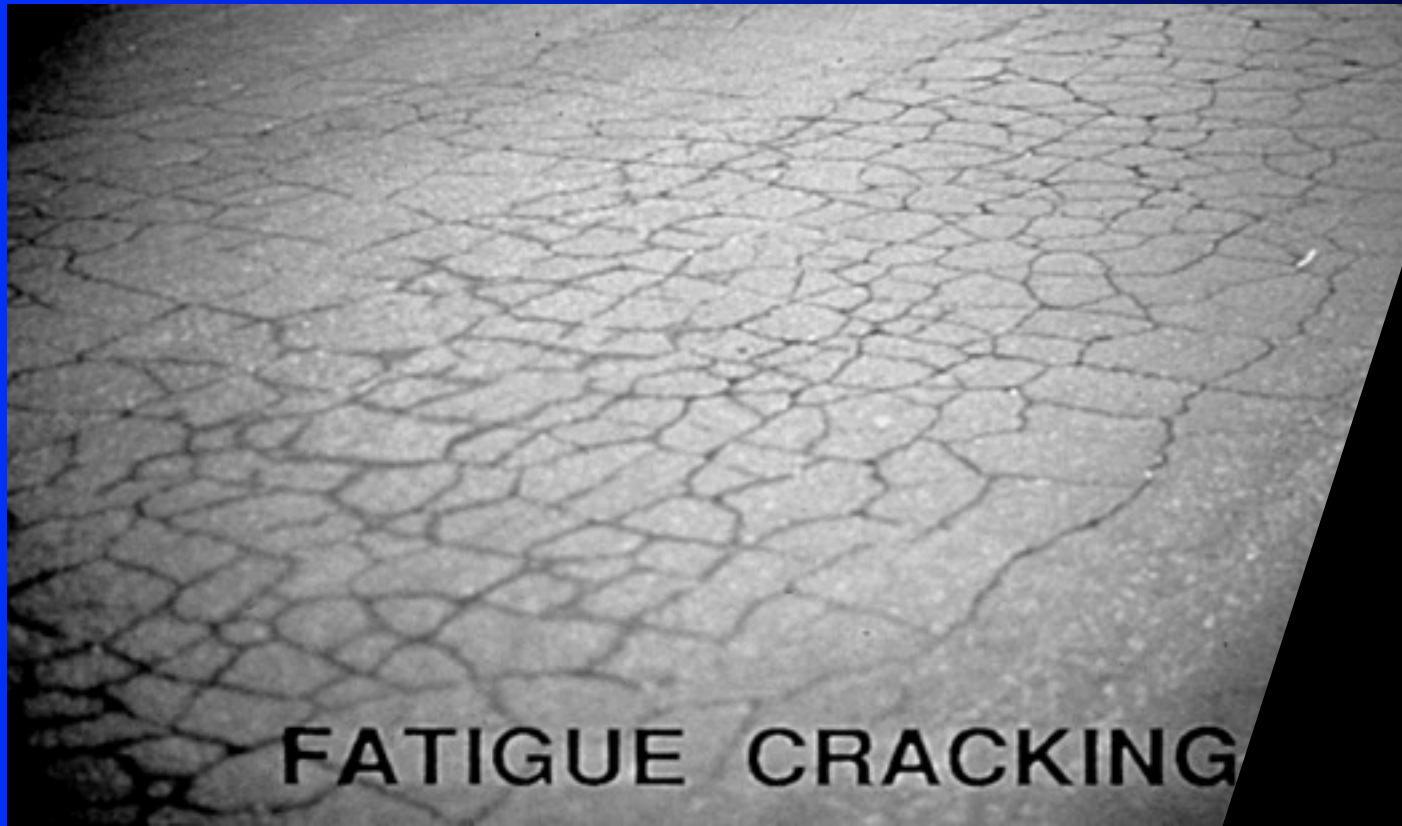


*> Early part of  
pavement life*

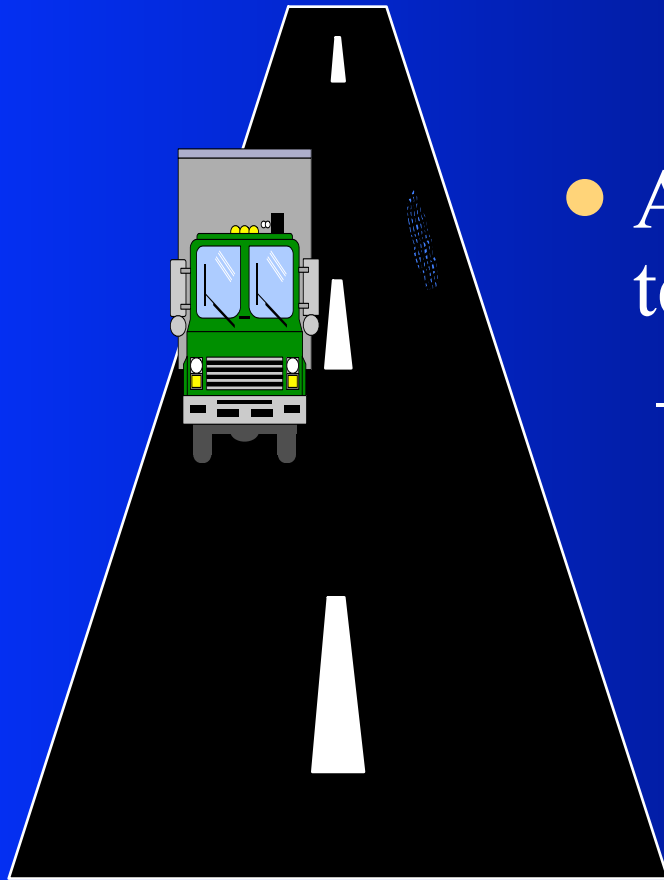
# Fatigue Cracking



# Fatigue Cracking

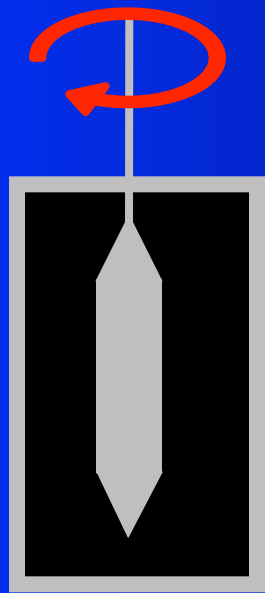


# Fatigue Cracking

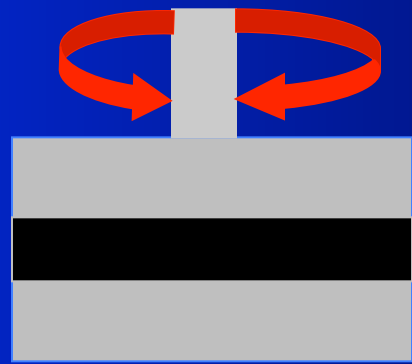


- Addressed by intermediate temperature stiffness
    - $G^* \sin \delta$  on RTFO & PAV aged binder  $\leq 5000$  kPa
- > *Later part of pavement service life*

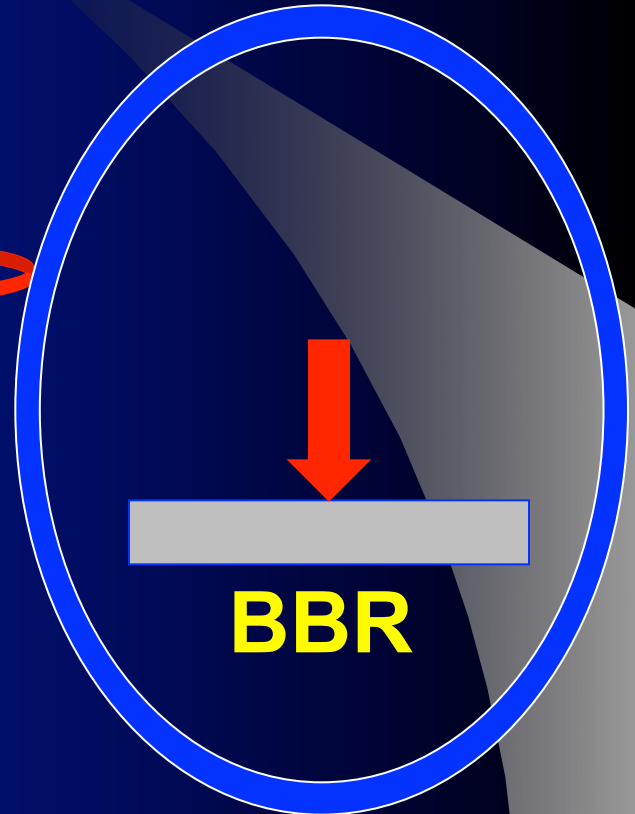
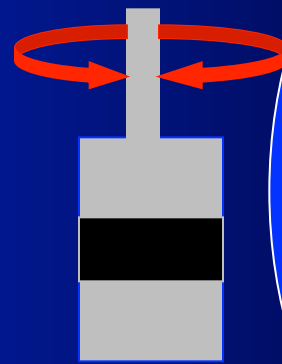
# Thermal Cracking



RV

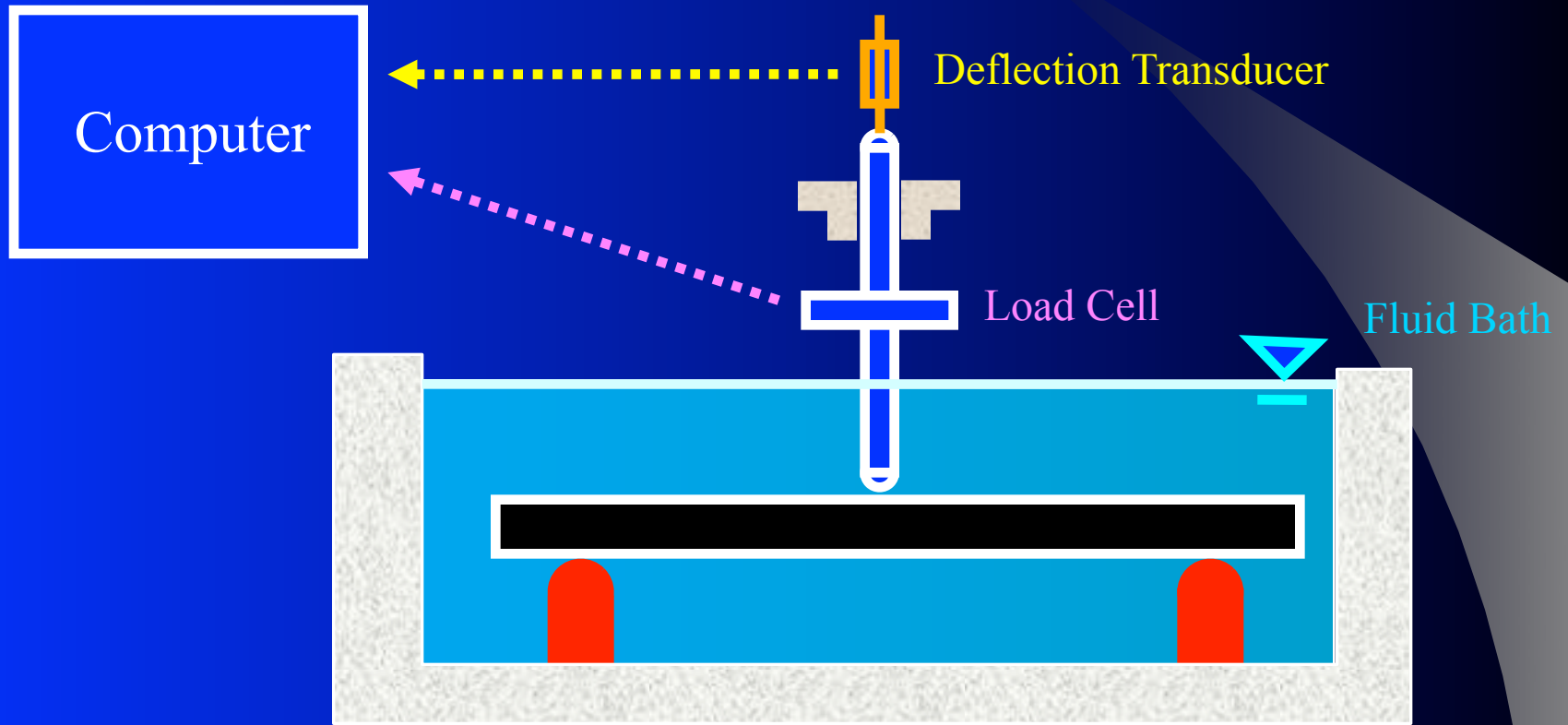


DSR



BBR

# Bending Beam Rheometer





# BBR Measures Stiffness at Low Temperatures using Beam Theory

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Creep stiffness at

$t = 60$  secs

$$S(t) = \frac{PL^3}{4bh^3\delta(t)}$$

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Clear Span of Beam, 102 mm

Beam Width, 12.5 mm

Beam Thickness, 6.25 mm

# BBR Measures Stiffness at Low Temperatures using Beam Theory

Creep stiffness at  
 $t = 60$  secs

$$S(t) = \frac{PL^3}{4bh^3\delta(t)}$$

100 grams

Clear Span of Beam, 102 mm

Deflection at  $t = 60$  secs

Beam Width, 12.5 mm

Beam Thickness, 6.25 mm

# Bending Beam Rheometer

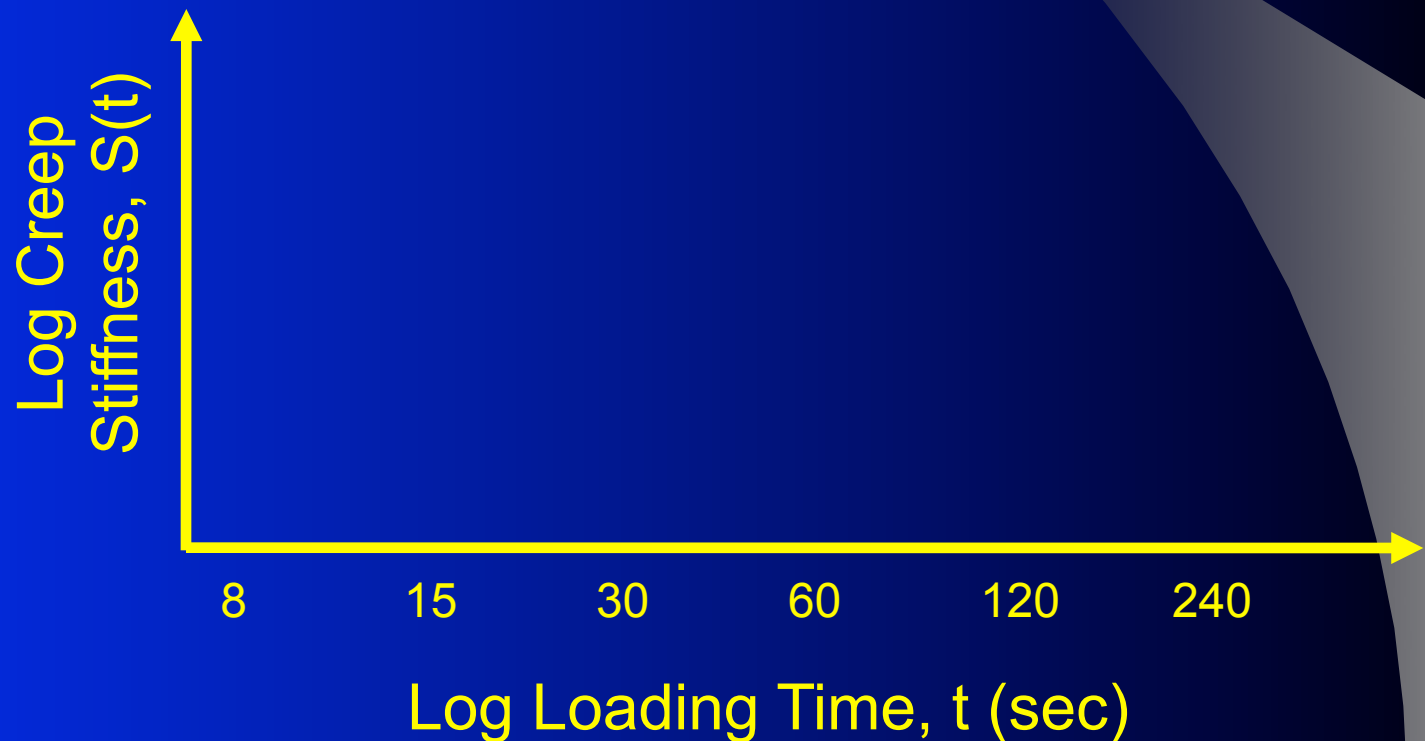
# Bending Beam Rheometer

- Creep Stiffness
- Stiffness v. Time Slope



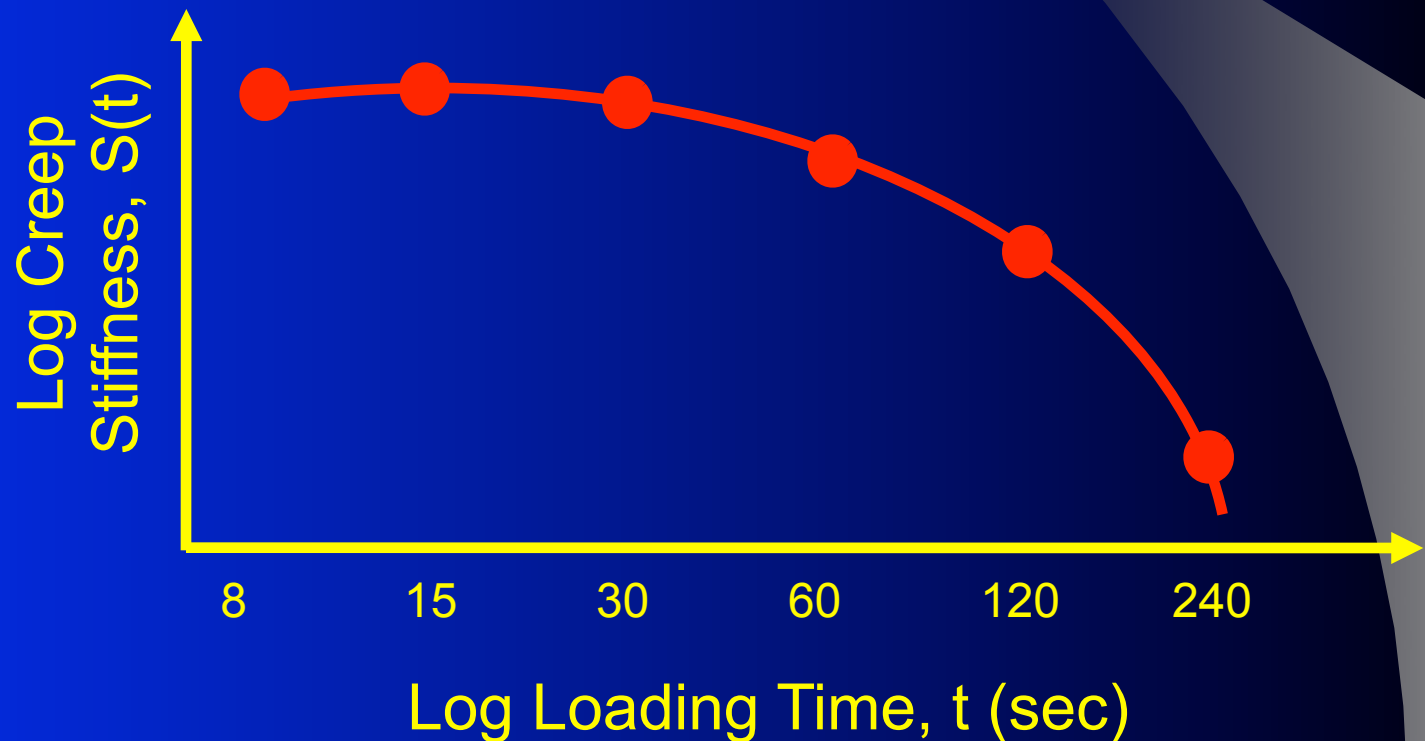
# Bending Beam Rheometer

- Creep Stiffness
- Stiffness v. Time Slope



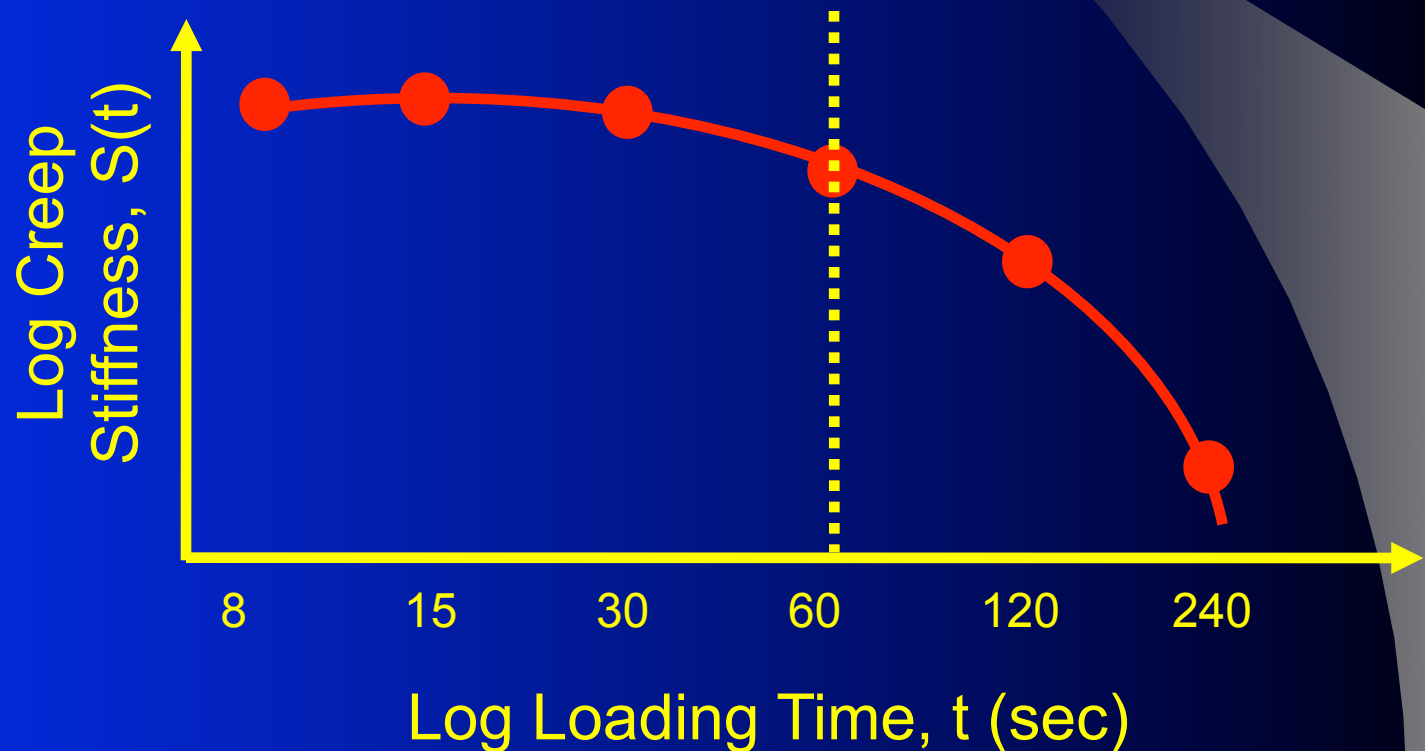
# Bending Beam Rheometer

- Creep Stiffness
- Stiffness v. Time Slope



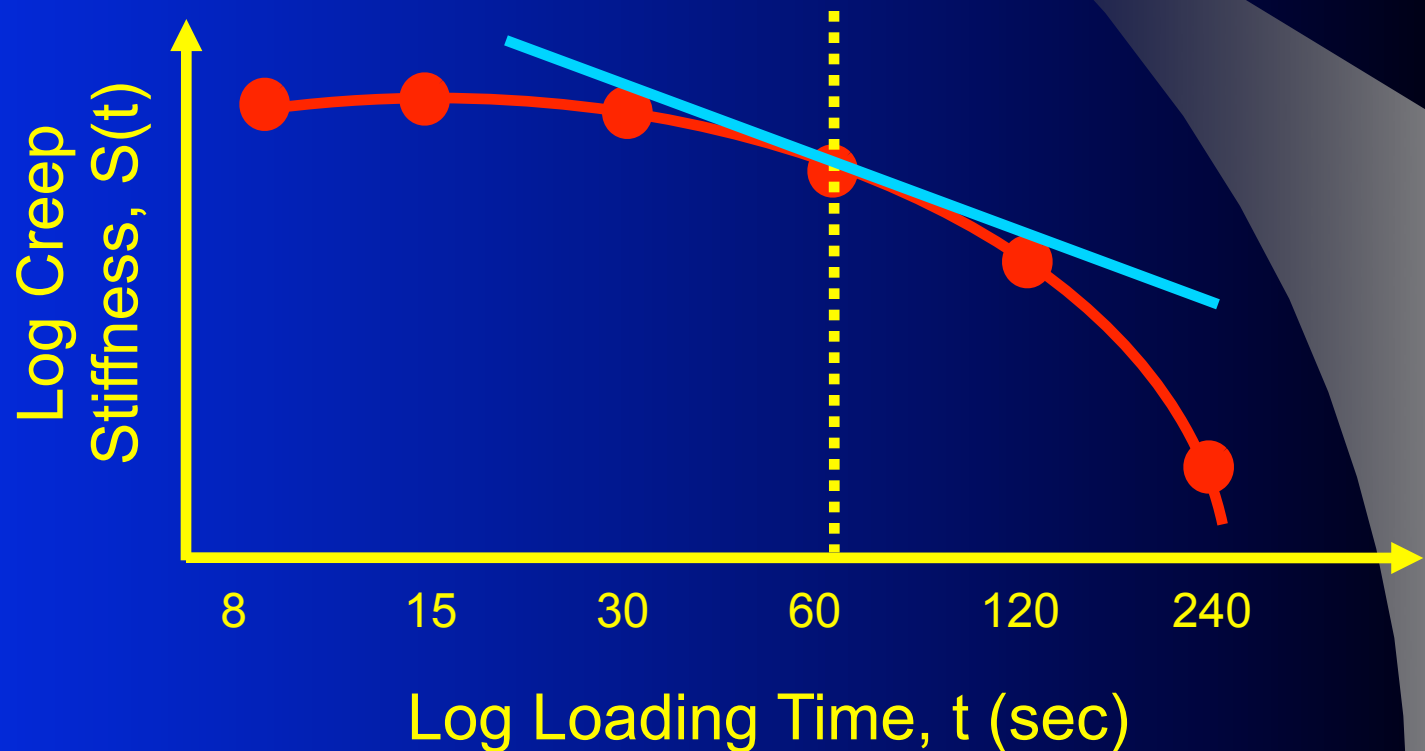
# Bending Beam Rheometer

- Creep Stiffness
- Stiffness v. Time Slope



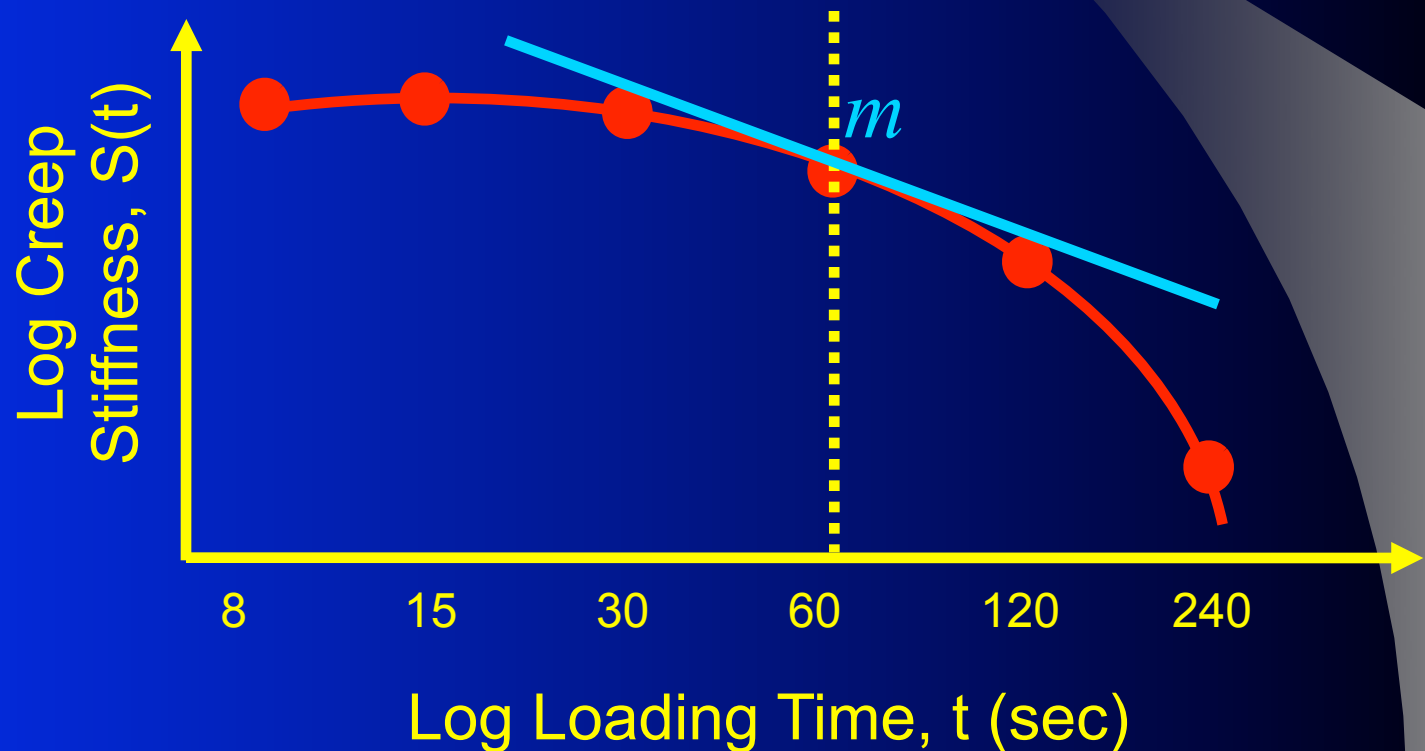
# Bending Beam Rheometer

- Creep Stiffness
- Stiffness v. Time Slope



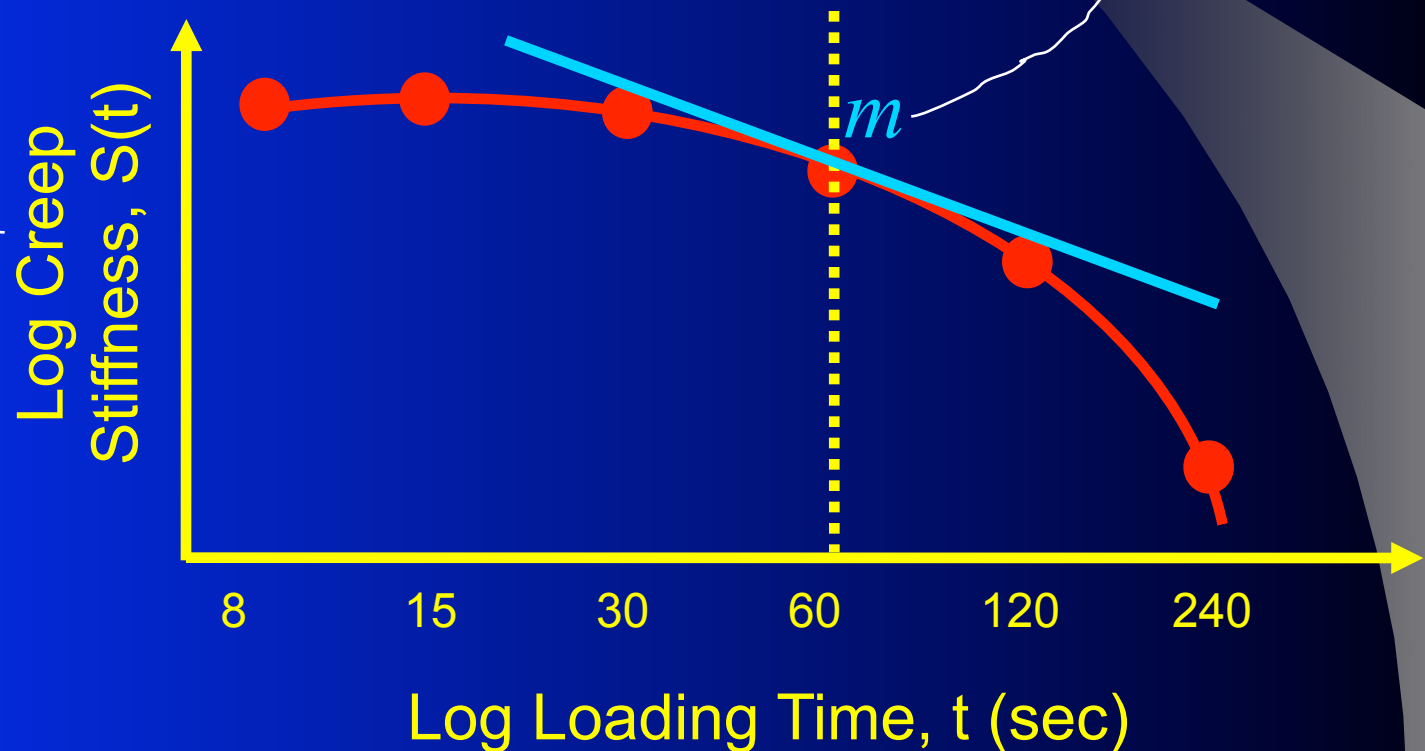
# Bending Beam Rheometer

- Creep Stiffness
- Stiffness v. Time Slope



# Bending Beam Rheometer

- Creep Stiffness
- Stiffness v. Time Slope



# Thermal Cracking

- Question: How Much Should the Asphalt Be Able to Stretch before Breaking?

# Thermal Cracking

- Question: How Much Should the Asphalt Be Able to Stretch before Breaking?

**Answer: at least 1%**

**How: Find the Temperature Where the Asphalt Can Stretch 1% or More**



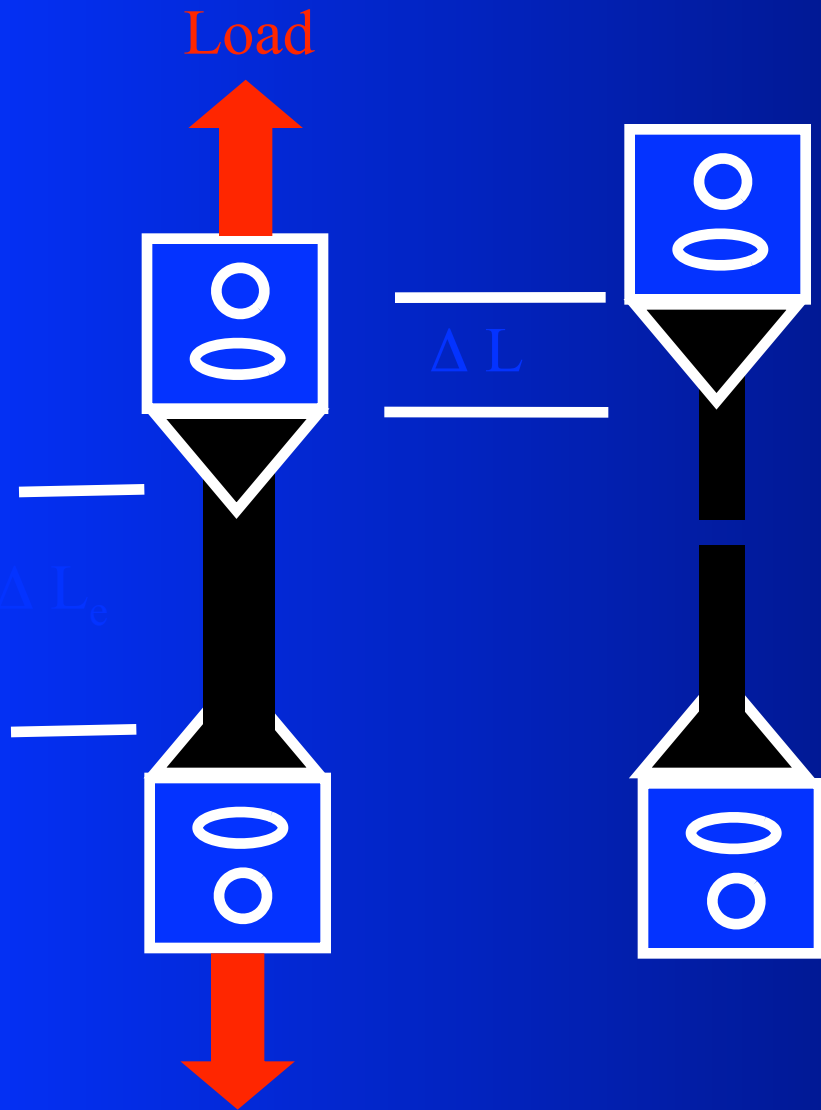
# Direct Tension Test



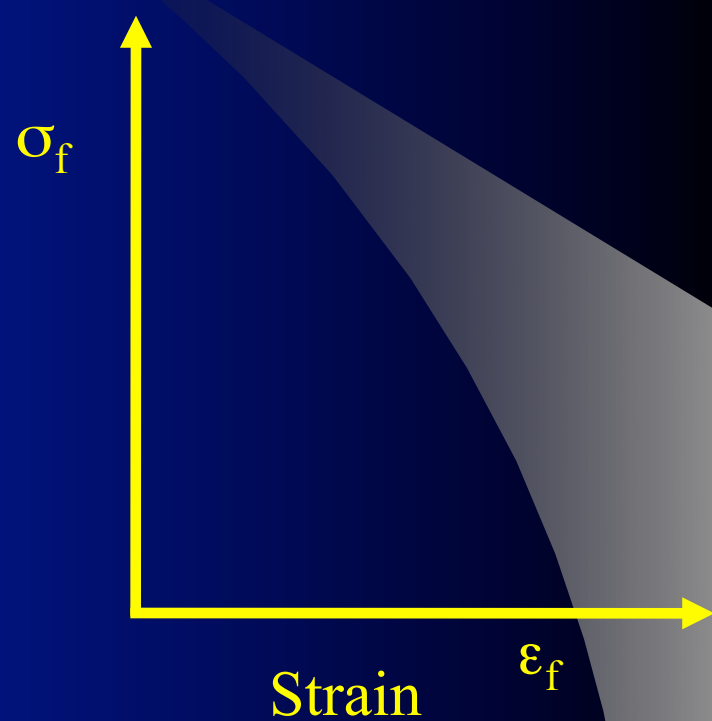
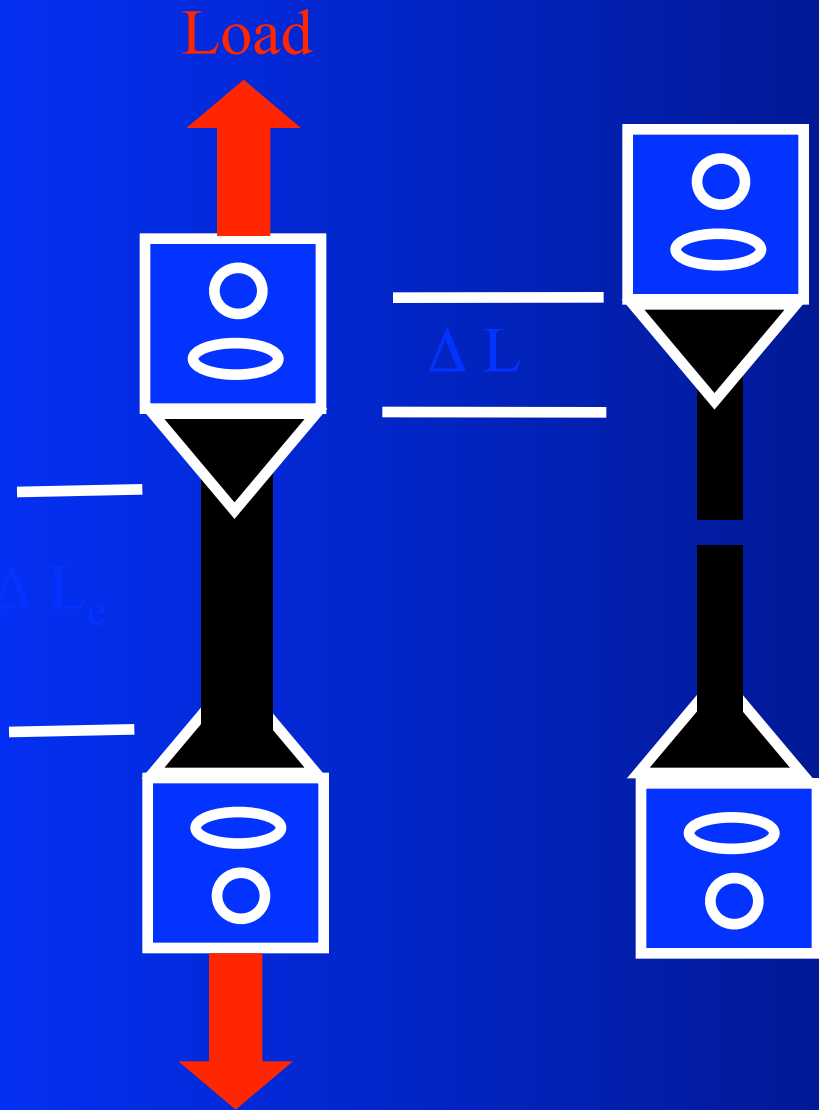
# Direct Tension Test



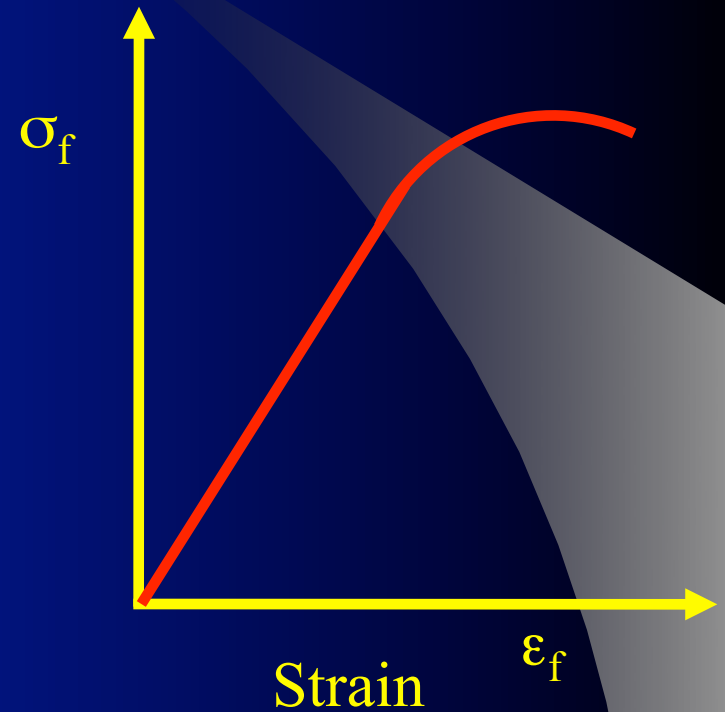
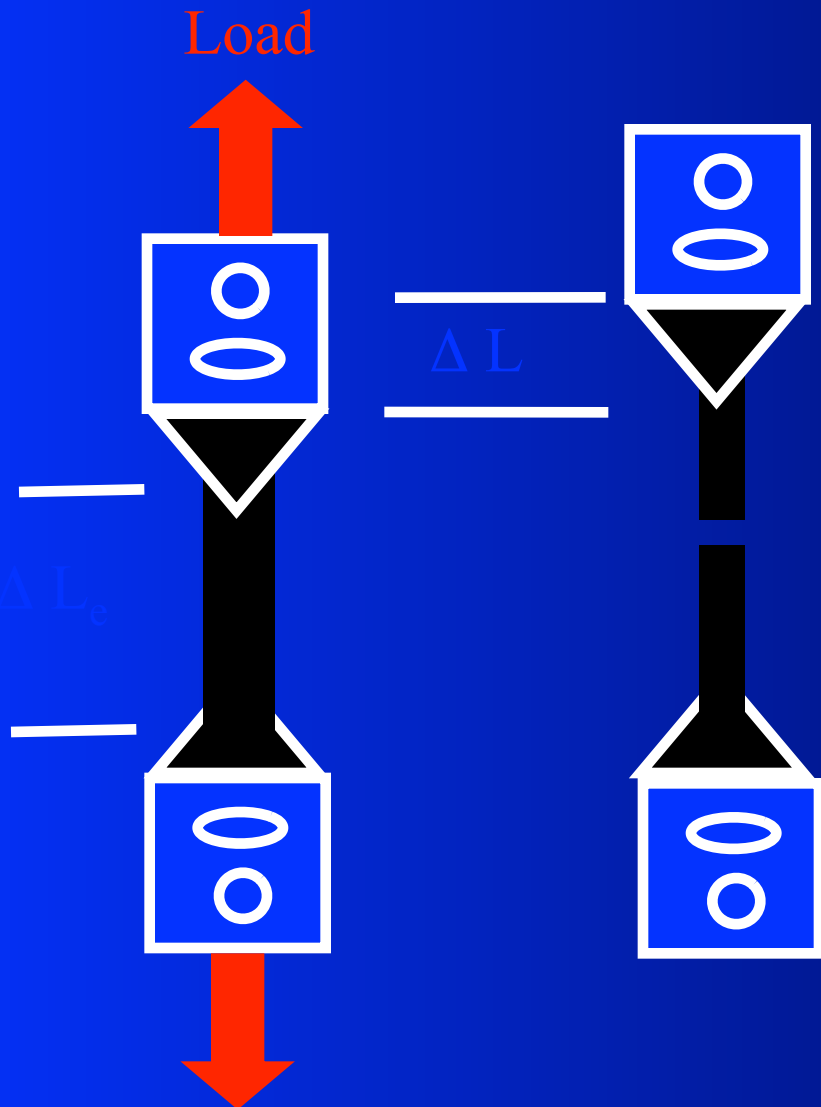
# Direct Tension Test



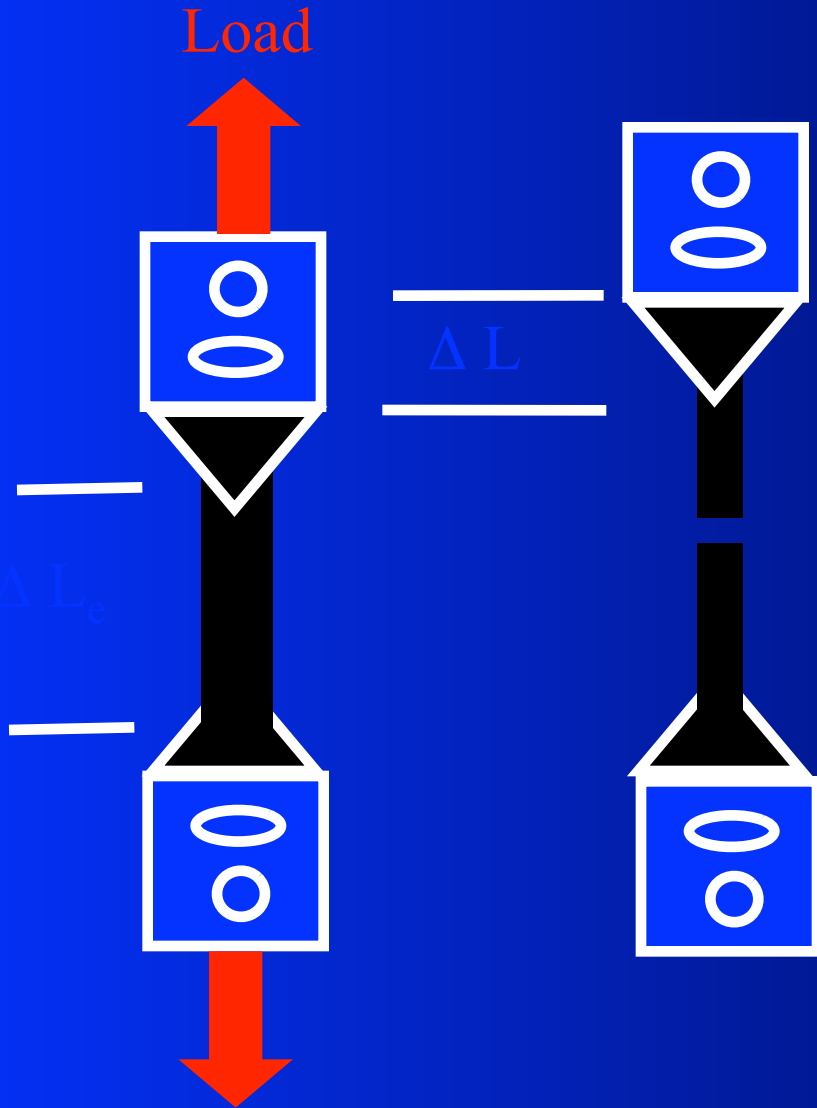
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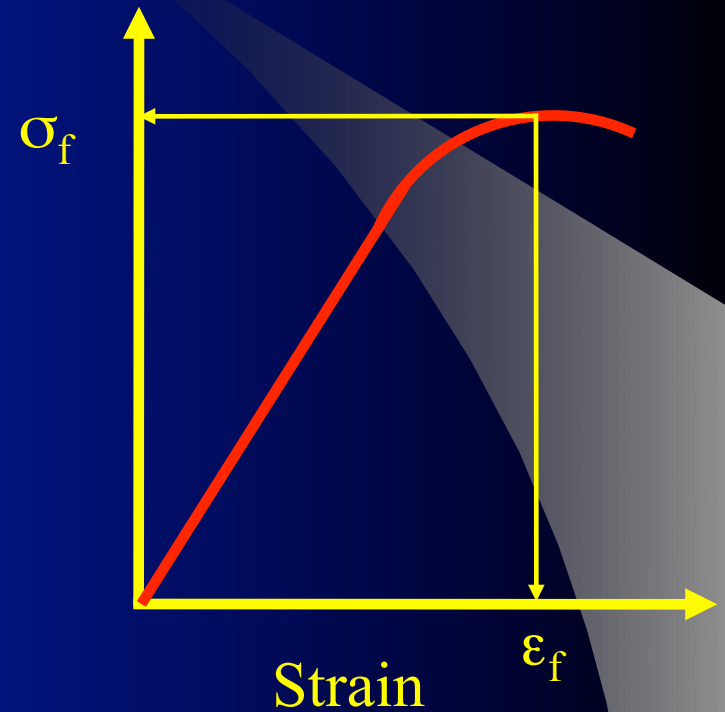
# Direct Tension Test



# Direct Tension Test

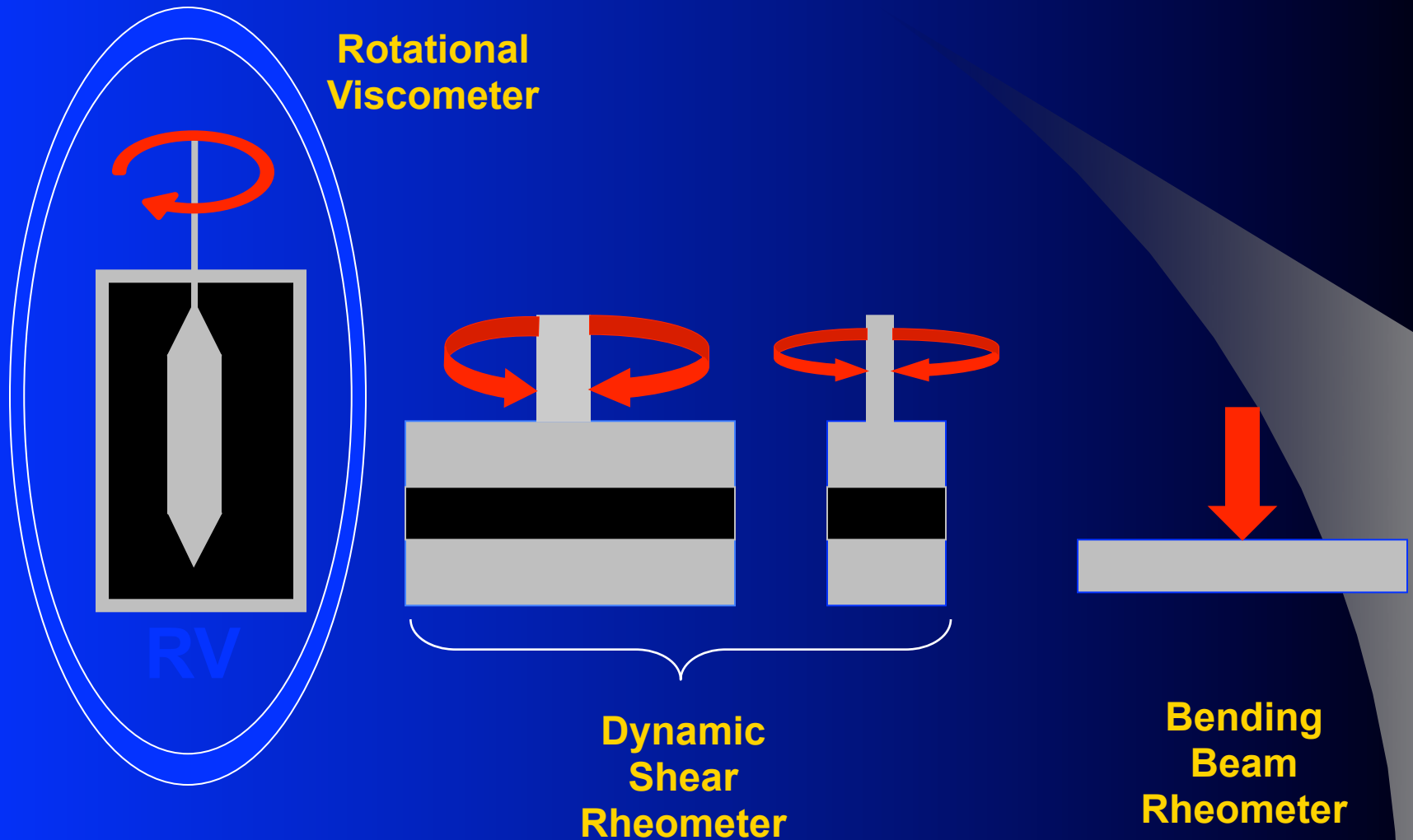


$$\text{Stress} = \sigma = P / A$$

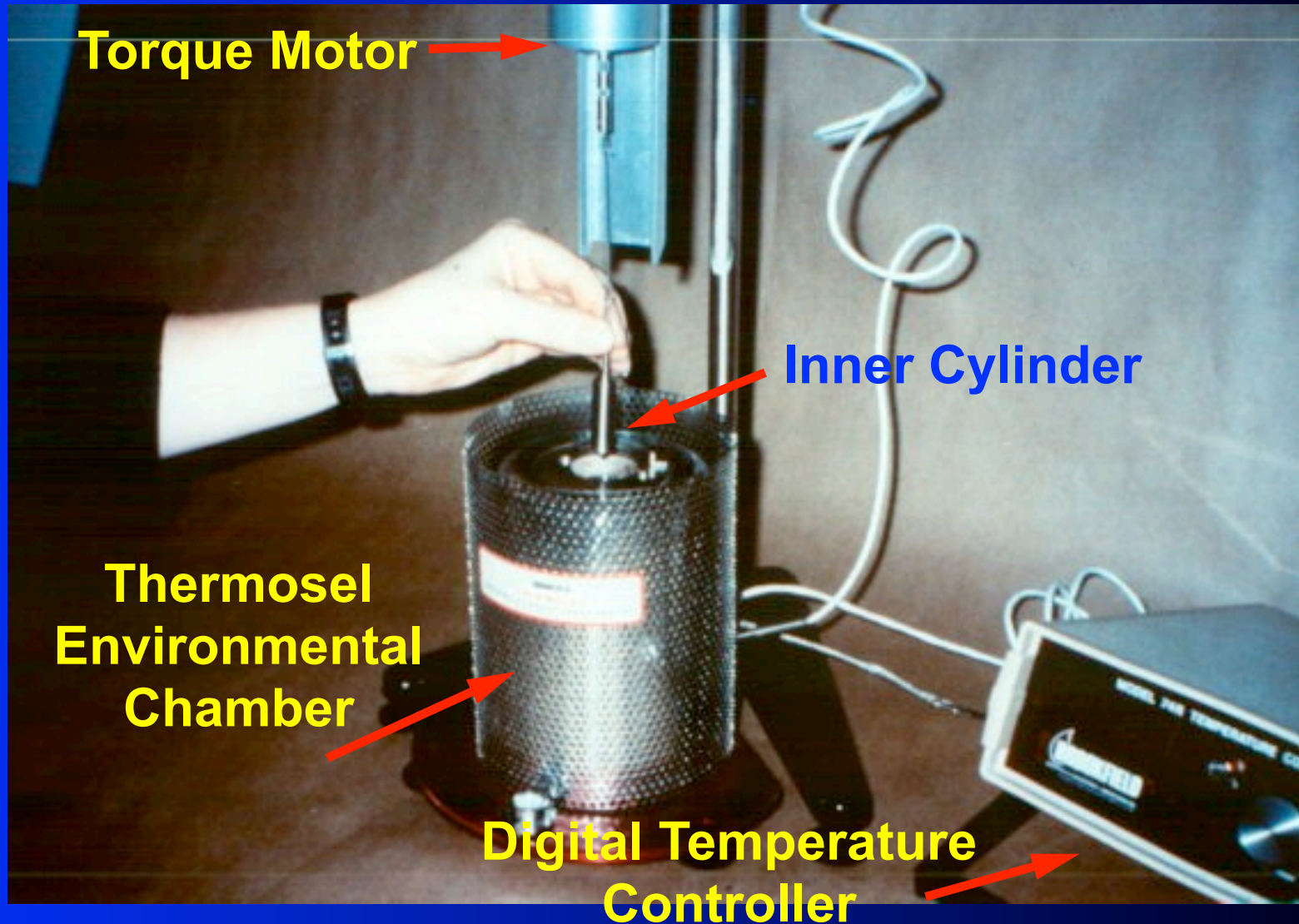


# But Will it Flow for Mixing ?

## Construction



# Rotational Viscometer (Brookfield)





# Spec Requirements

- Make Sure It's Not Too Thick
  - Keep Viscosity Below 3 Pa-sec at 275F (135C)

A cartoon illustration of a turtle with a green, patterned shell and a pink body, walking on a paved road with yellow double lines. Above the turtle is a large, white, cloud-like thought bubble containing the text "Questions...". The background shows a real-world road curving through a grassy area.

Questions...