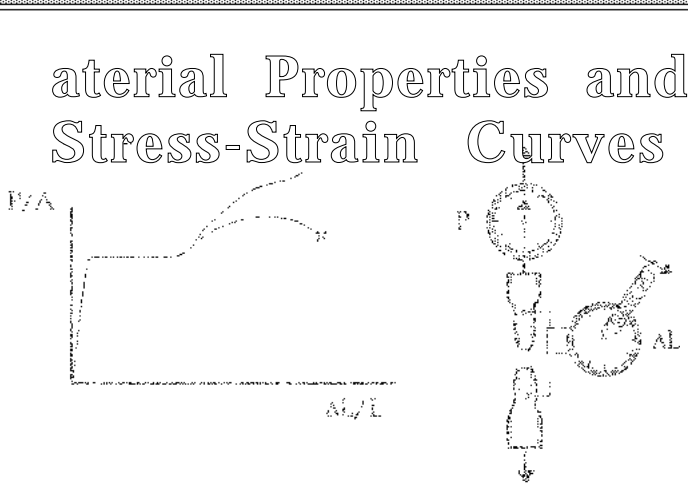


Material Properties and Stress-Strain Curves



The image shows a stress-strain graph on the left with a vertical axis labeled P/A and a horizontal axis labeled A_0/L . The curve starts at the origin, rises linearly, then curves upwards to a peak, and finally curves downwards. To the right of the graph is a diagram of a tensile specimen, a vertical bar with a central narrow section, being pulled apart by forces P at both ends. A circular cross-section of the specimen is shown to the right, with a diameter labeled A_0 .

2

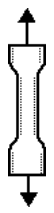
Table of Contents

- Tensile Test -- Steel
- Loading / Unloading
- Stress-Strain Curve Properties
- Tensile Test -- Aluminum

2

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Tensile Test



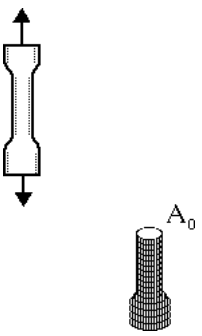
A diagram of a tensile specimen, a vertical bar with a central narrow section, being pulled apart by forces at both ends, indicated by upward and downward arrows.

One of the most common means for characterizing the basic stress-strain behavior of a material is to perform a simple tensile test. A small specimen of the material in question is made and loaded as shown. The shape shown is typical for metals.

3

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Tensile Test



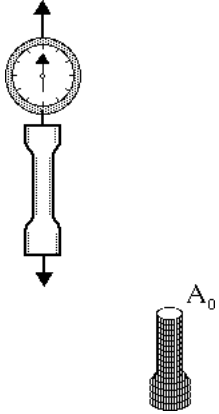
A diagram of a tensile specimen being pulled apart, and a cutaway diagram of a bolt with a cross-sectional area labeled A_0 .

As the cutaway below indicates, these specimens are axisymmetric, and are designed such that they will fail in the central portion rather than at the ends. The size and cross-sectional area (A_0) of a specimen is standardized for a given material.

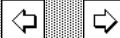
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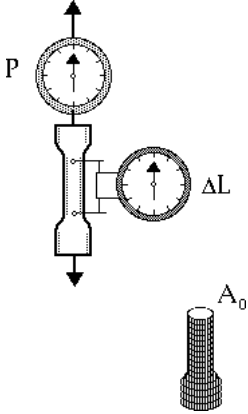
Tensile Test



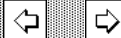
To obtain useful results, the magnitude of the load is measured during the test. Here we show a simple force meter.

5 Hide Text 

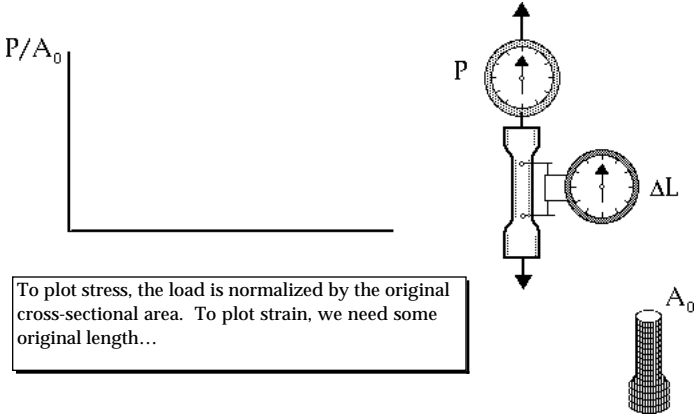
Tensile Test



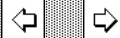
To construct a stress-strain plot, it is necessary to measure deformation as well as force, and so we show a displacement meter as well.

6 Hide Text  testing machine

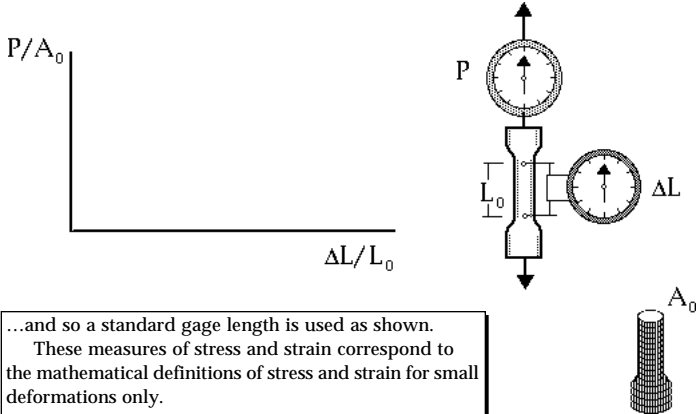
Tensile Test



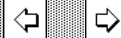
To plot stress, the load is normalized by the original cross-sectional area. To plot strain, we need some original length...

7 Hide Text 

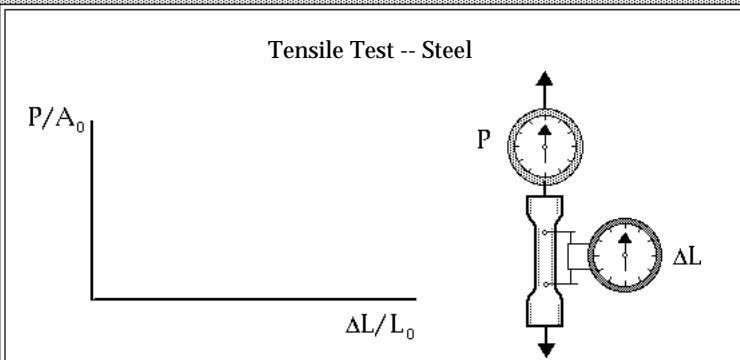
Tensile Test



...and so a standard gage length is used as shown. These measures of stress and strain correspond to the mathematical definitions of stress and strain for small deformations only.

8 Hide Text 

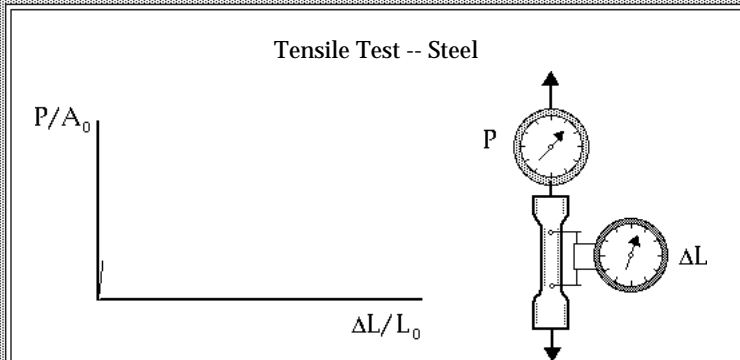
Tensile Test -- Steel



We will now simulate a tensile test of a typical mild steel specimen. Load and deformation will be indicated on the gages, and plotted on the curve.

9 Hide Text

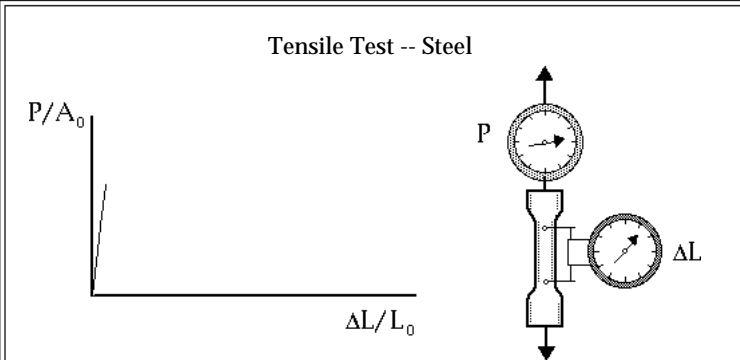
Tensile Test -- Steel



As load is applied, a proportional displacement is observed.

10 Hide Text

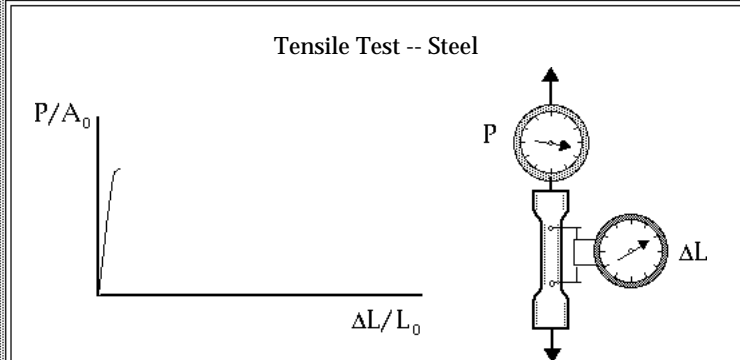
Tensile Test -- Steel



This linear behavior continues.

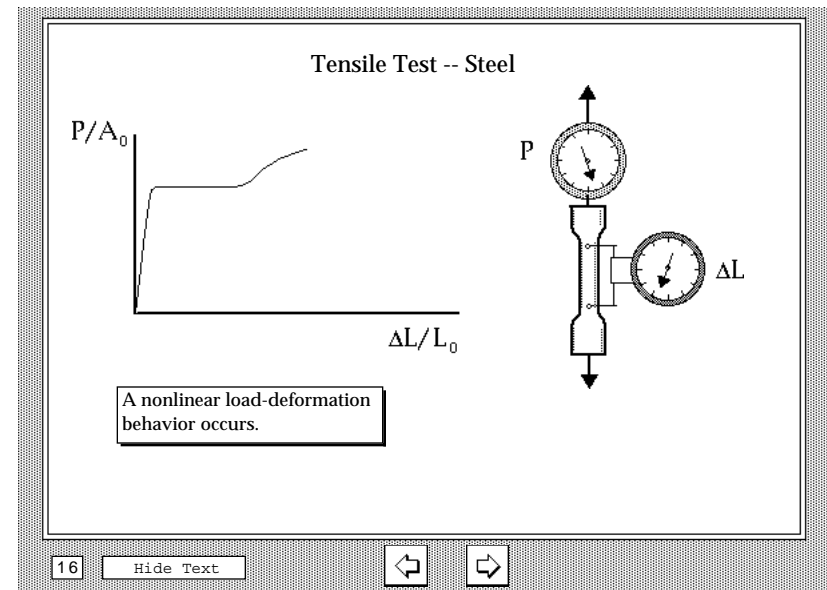
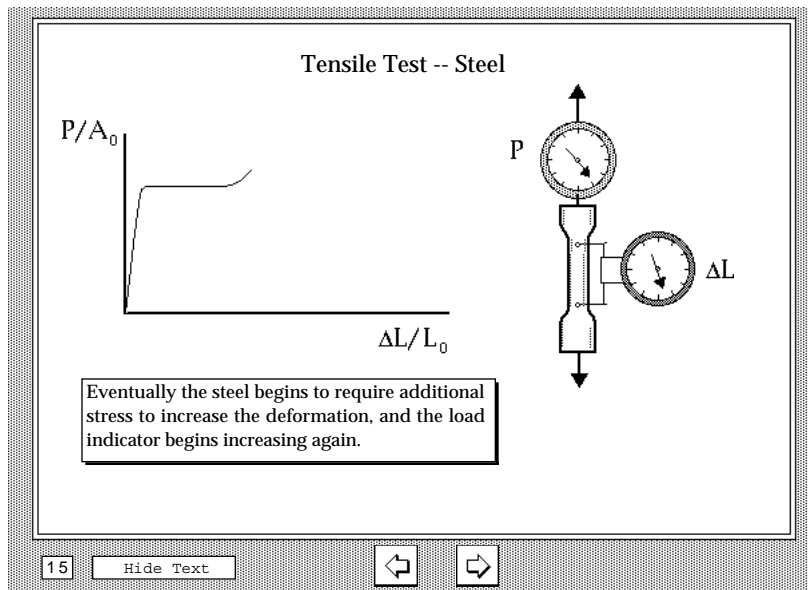
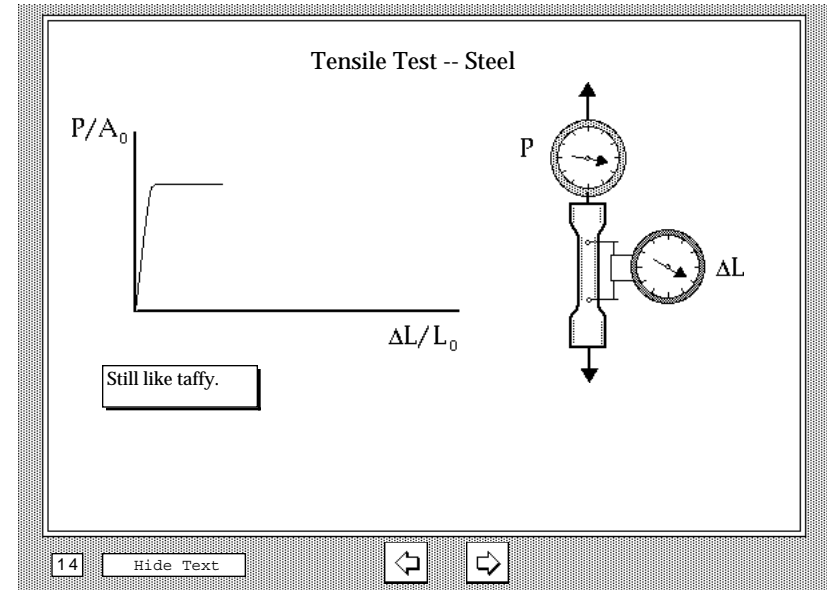
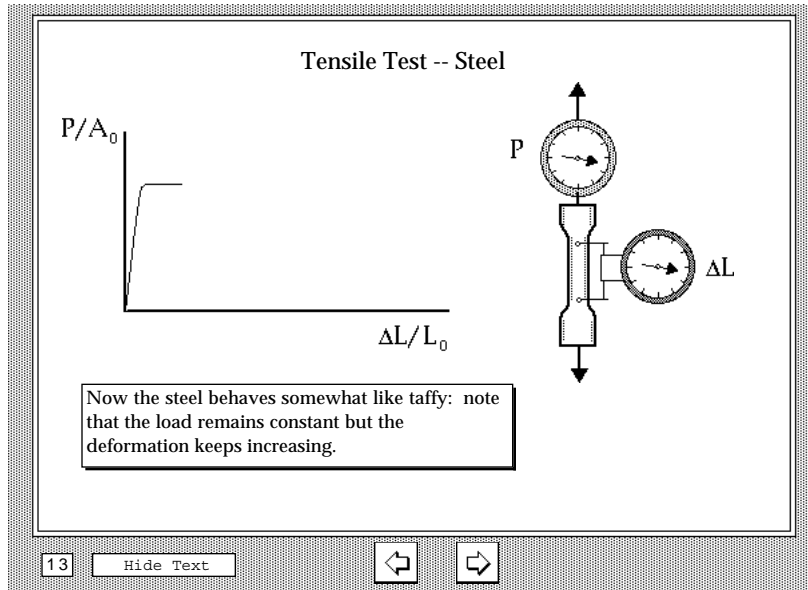
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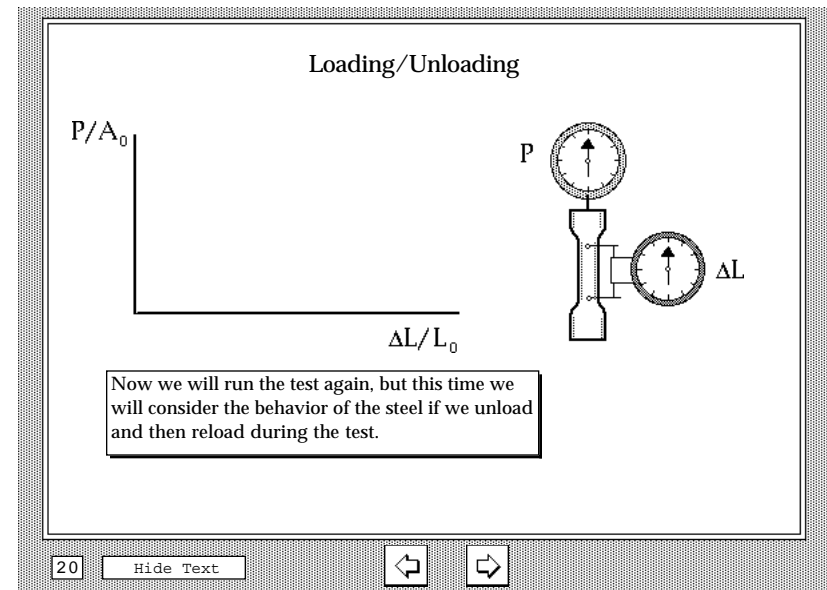
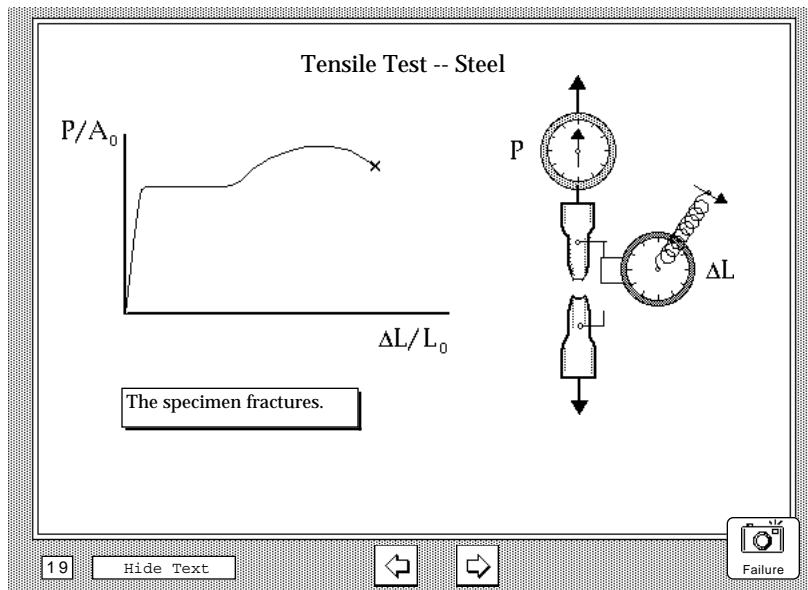
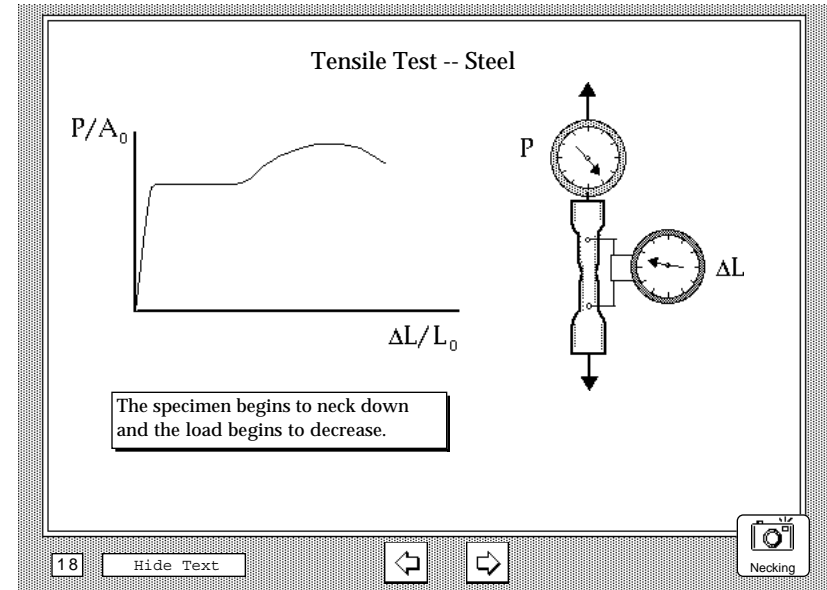
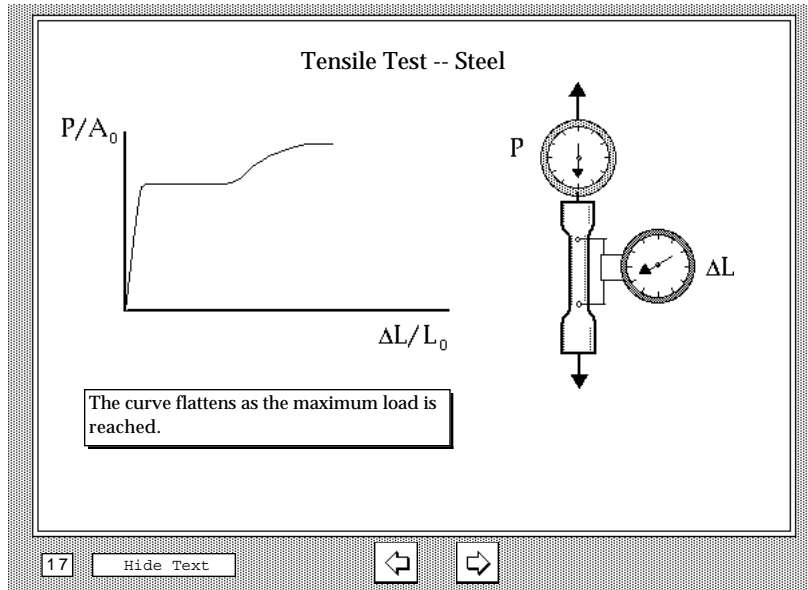
Tensile Test -- Steel

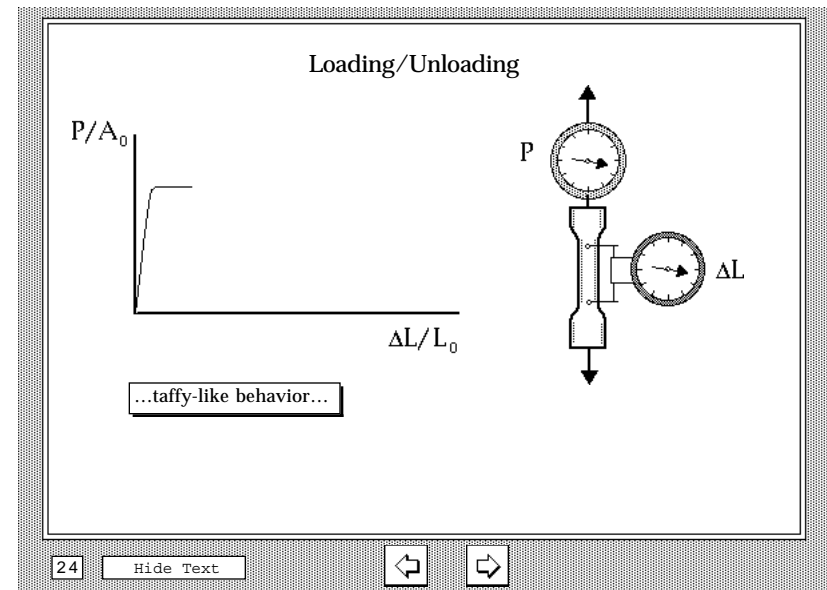
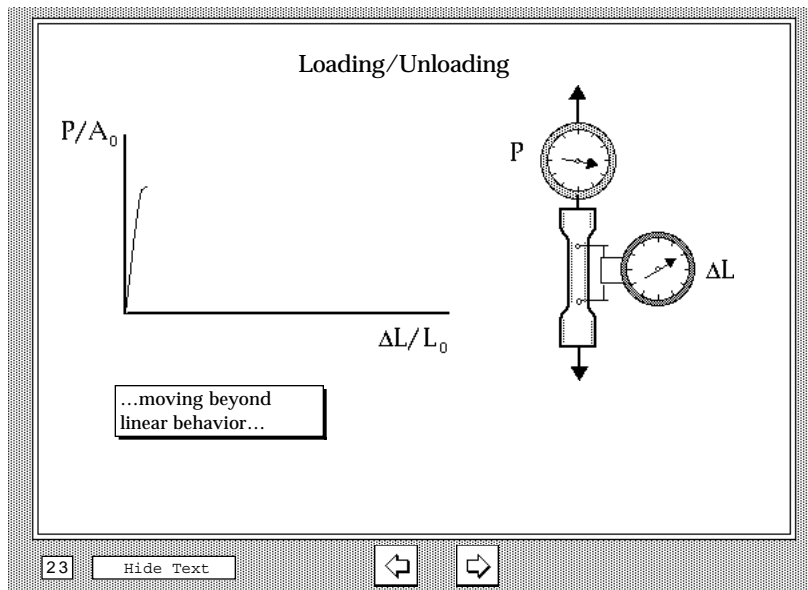
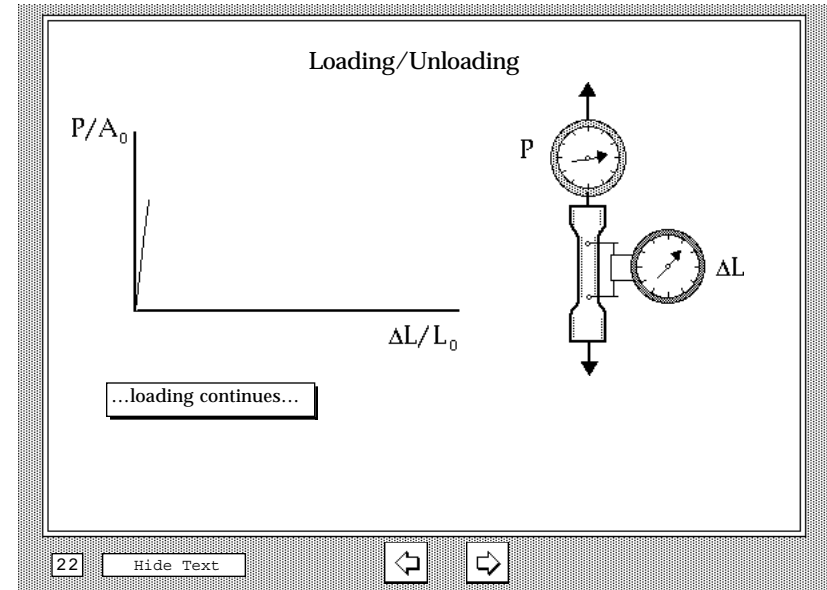
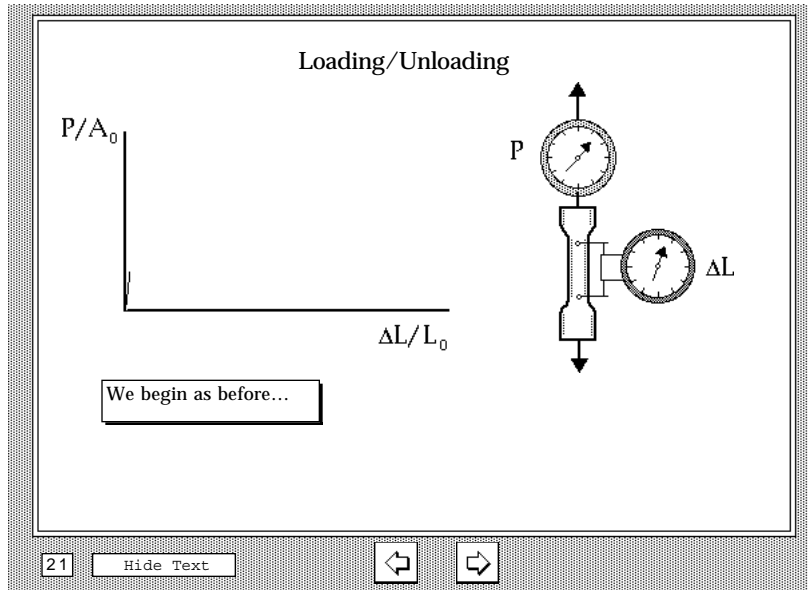


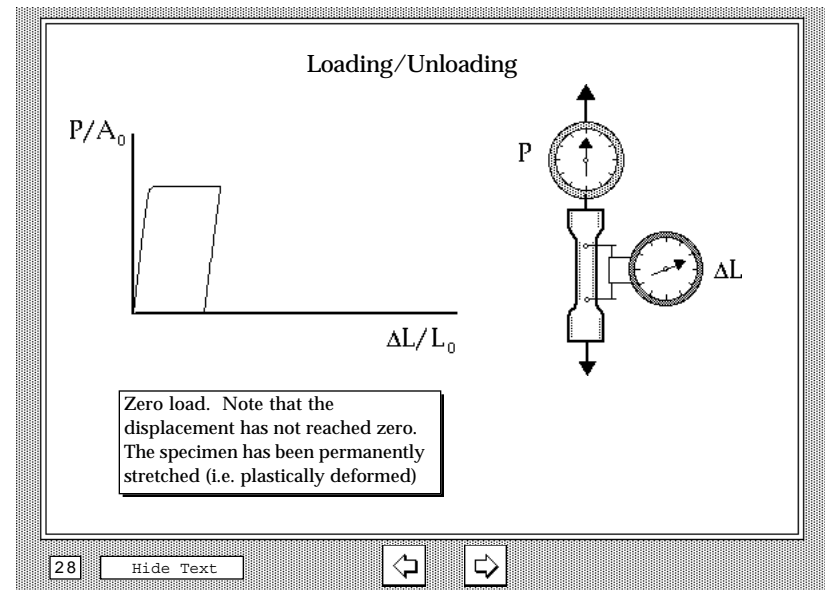
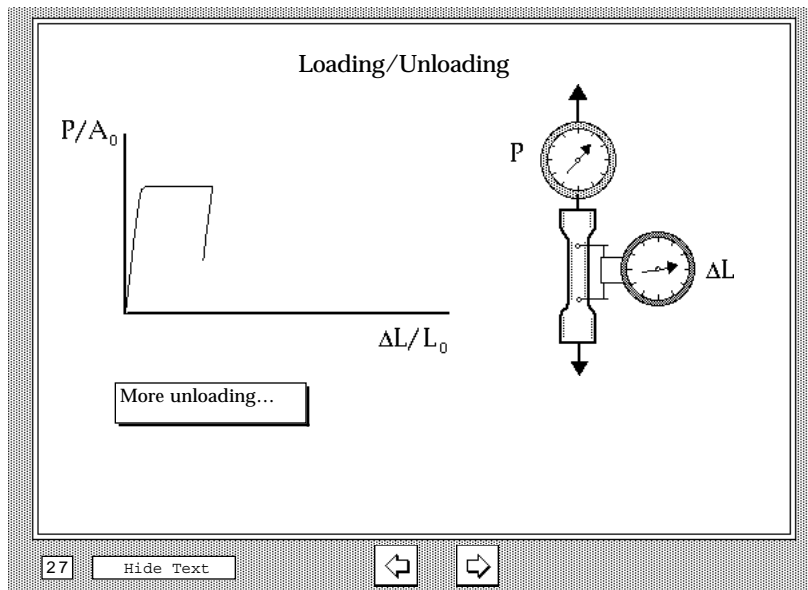
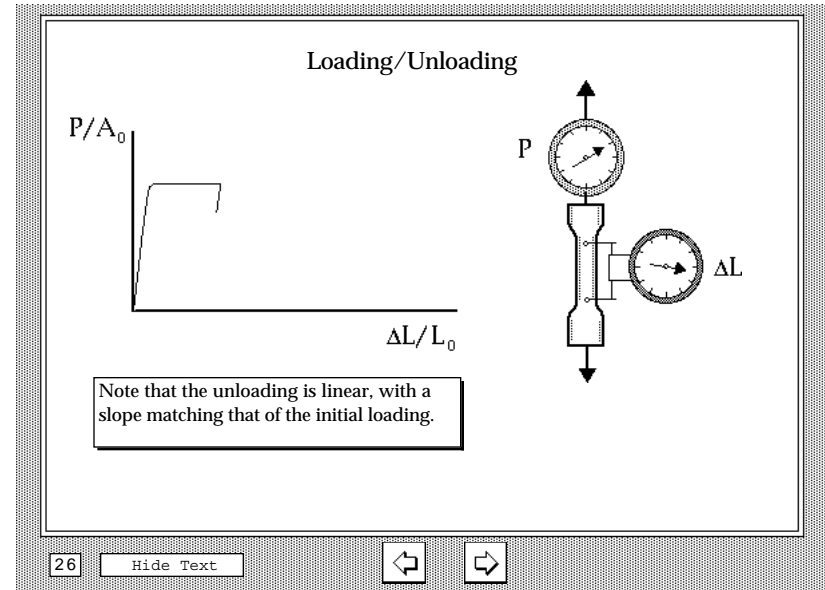
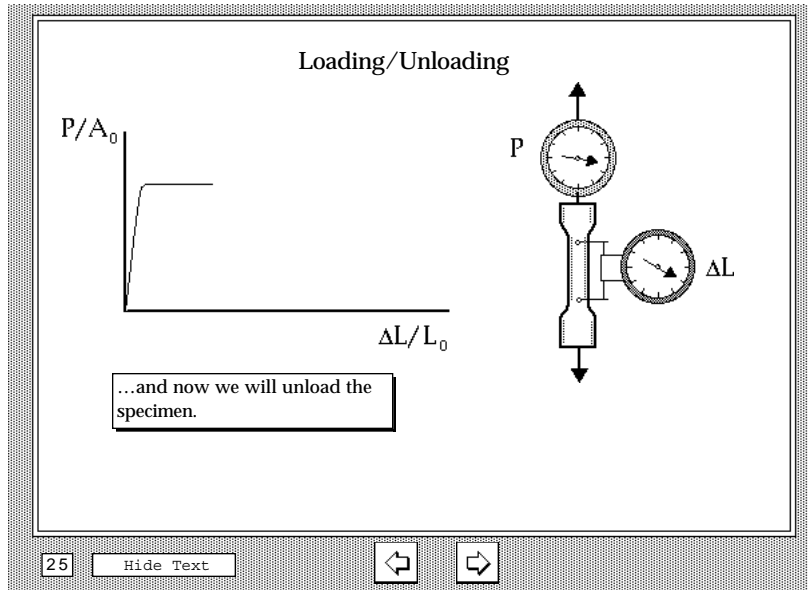
At a higher stress, there is a change from linear behavior as shown.

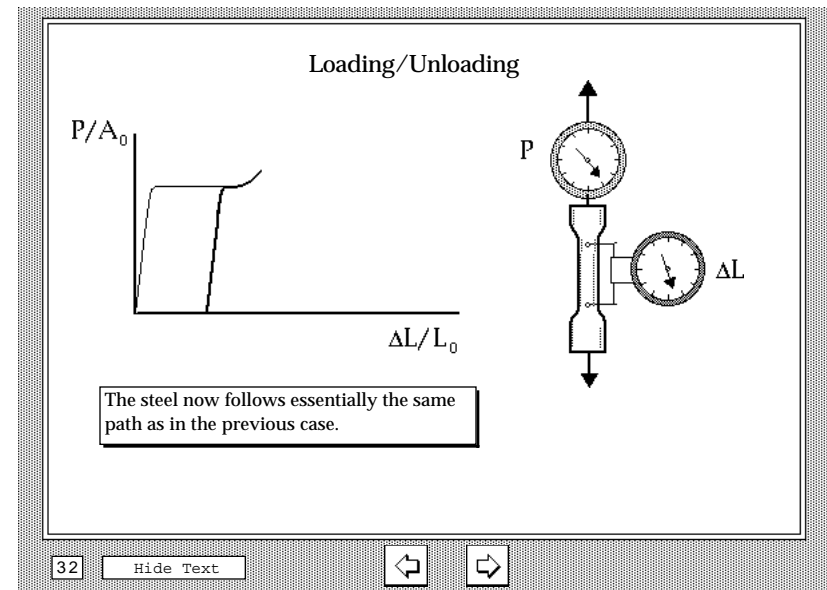
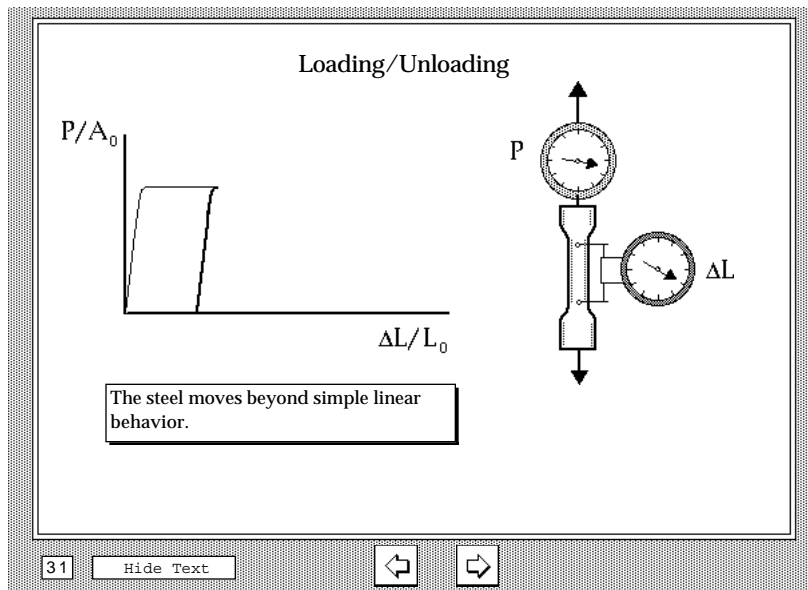
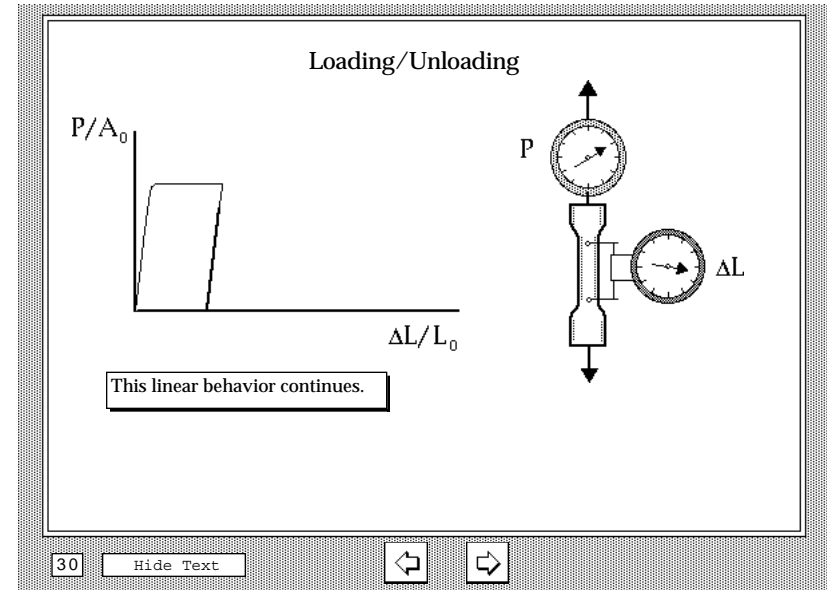
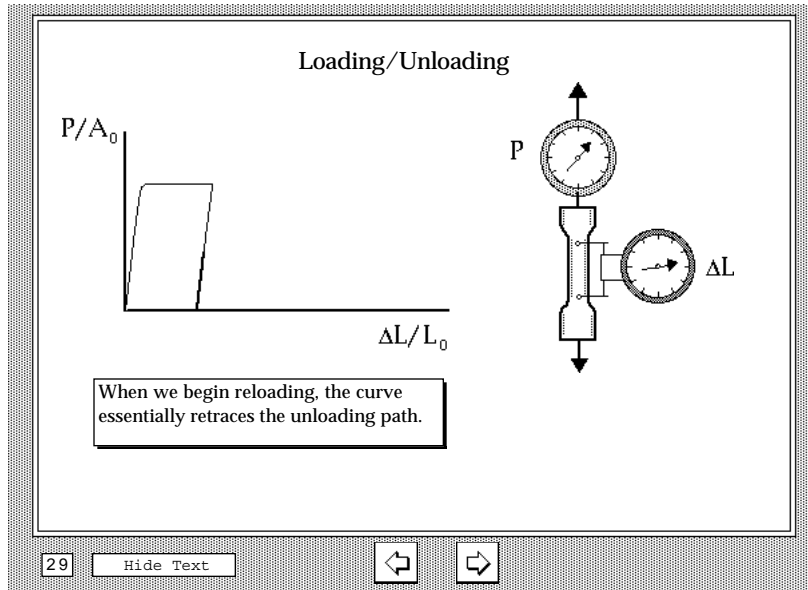
12 Hide Text

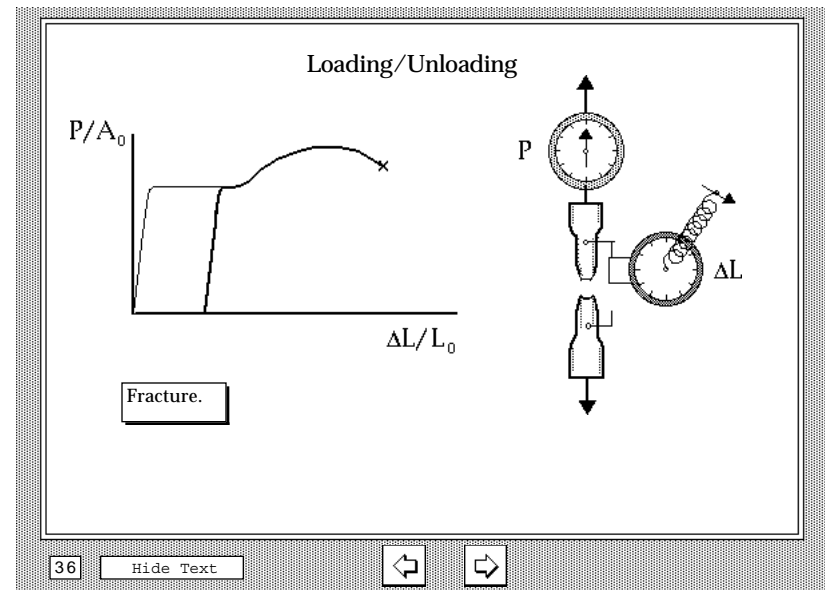
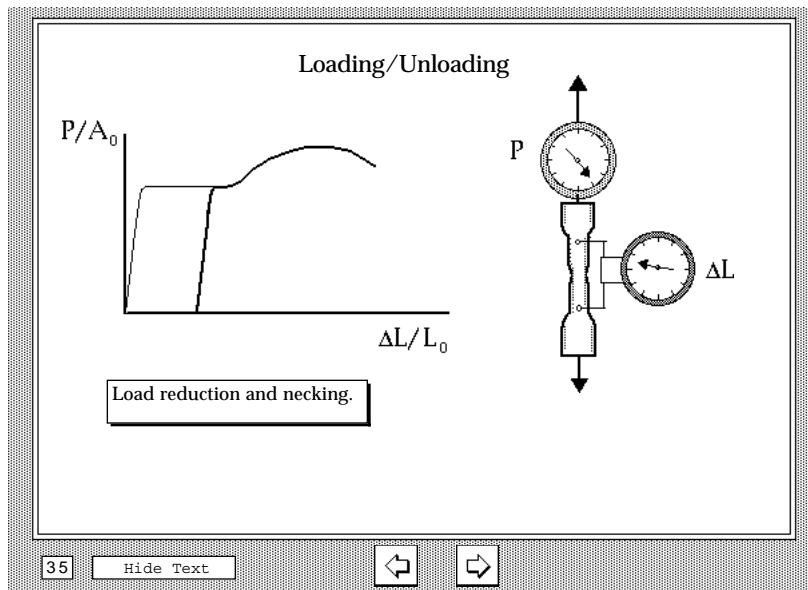
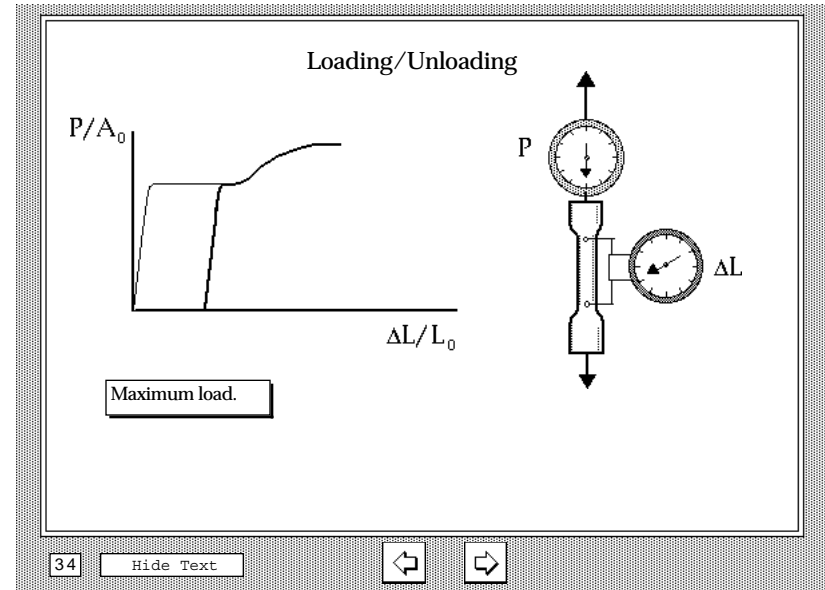
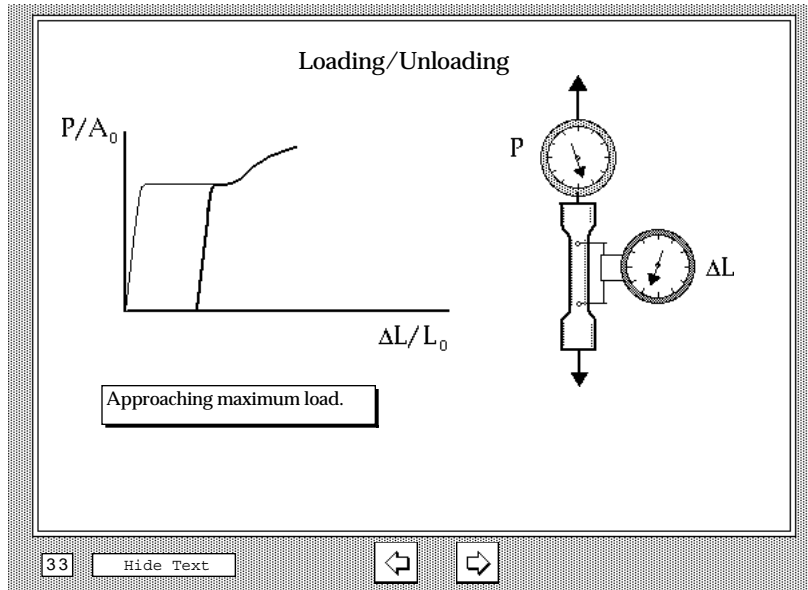












Properties of the Stress-Strain Curve

We will now introduce some basic terminology used in discussing and quantifying stress-strain behavior.

37 Hide Text ⏪ ⏩

Tensile Test -- Steel

We will run the steel test yet again, but this time we will add some terminology.

38 Hide Text ⏪ ⏩

Tensile Test -- Steel

As shown, the initial behavior is **linear**. Furthermore, if the load were removed now, the specimen would return to its original state. The deformation is thus **elastic**. The behavior is termed **linear-elastic**.

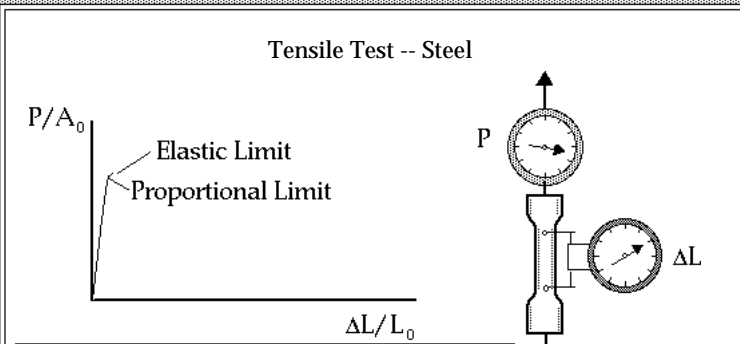
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Tensile Test -- Steel

The initial slope of the stress-strain curve measures the elastic stiffness of the material, and is defined as the Modulus of Elasticity.

40 Hide Text ⏪ ⏩

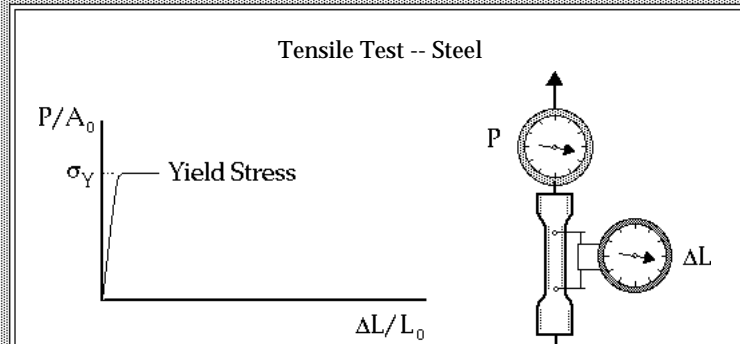
Tensile Test -- Steel



There are two aspects to the end of linear-elastic behavior. First, the response becomes non-linear (i.e. load and displacement are no longer proportional) at the proportional limit. Second, the deformations become permanent (plastic) beyond the elastic limit. For mild steel these limits are quite close to each other.

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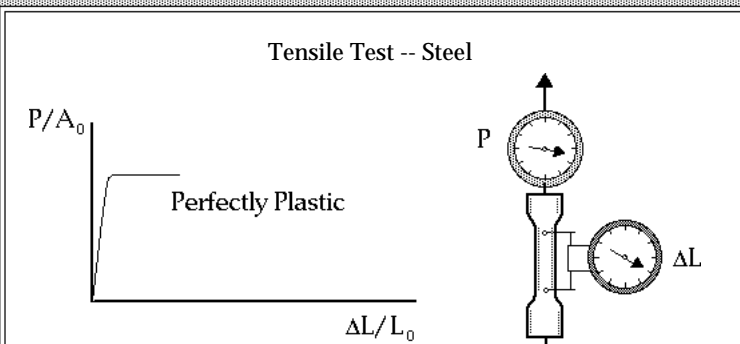
Tensile Test -- Steel



Once a material has been loaded beyond the elastic limit, it is said to have **yielded**. This "tuffy" stress is very important for design purposes, since it provides a limit to the amount of stress a material can sustain without becoming permanently stretched. This limit stress is called the **yield stress**.

42 Hide Text ↩ ➡

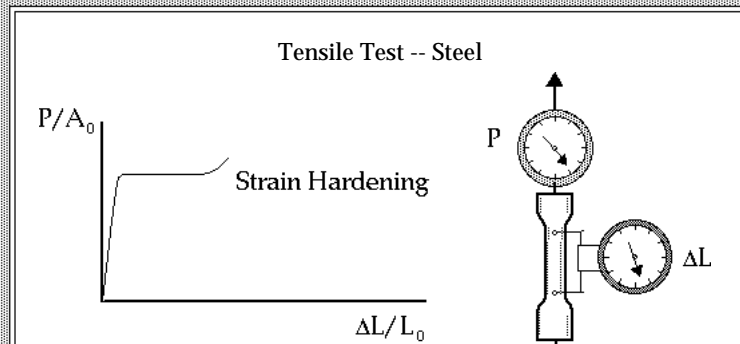
Tensile Test -- Steel



This clear plateau in the stress-strain curve is a peculiar but important property of steel. Increasing strain with constant load is called perfectly plastic behavior.

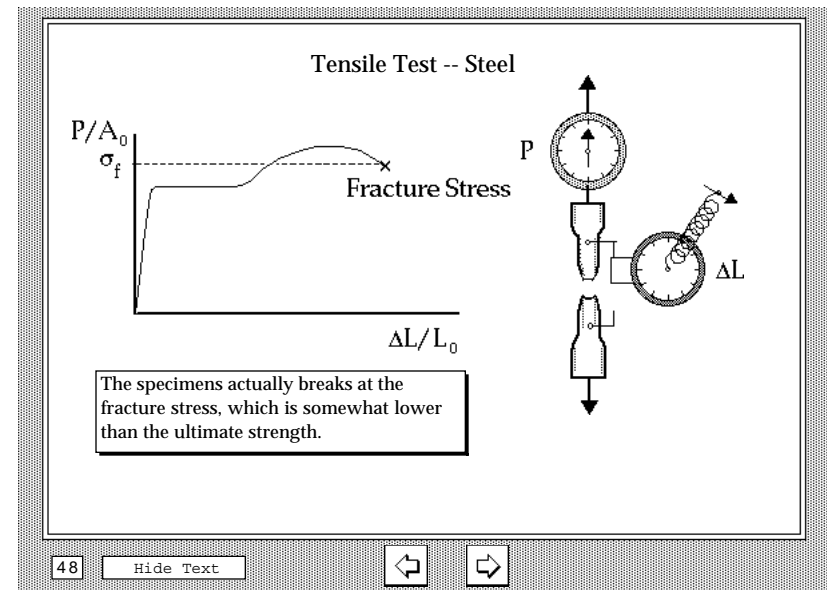
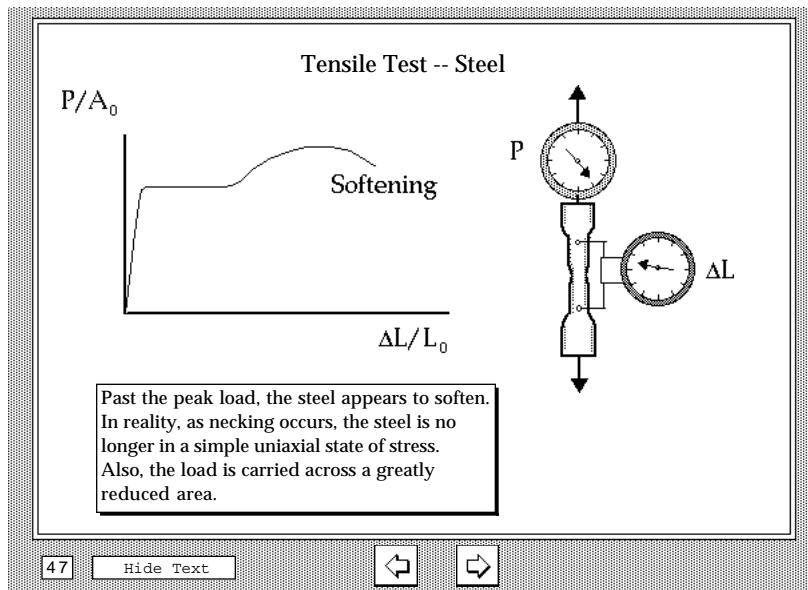
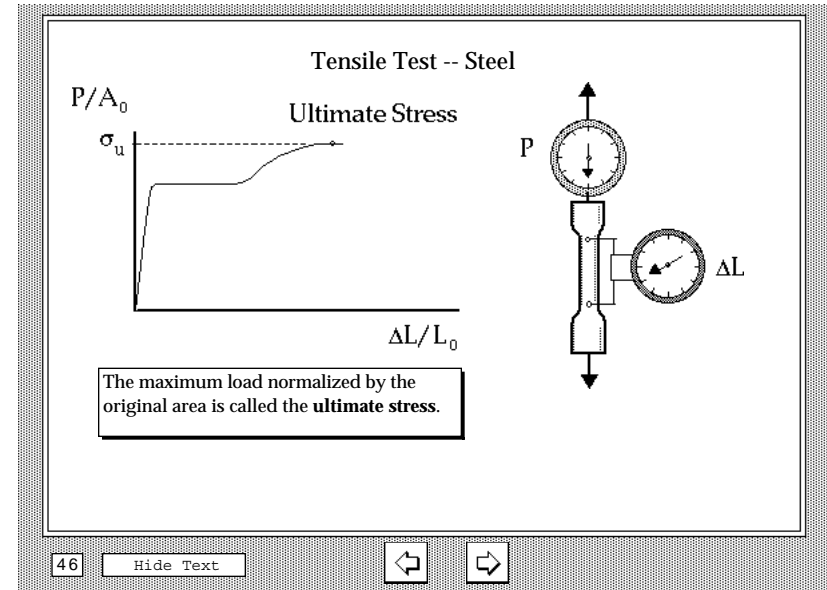
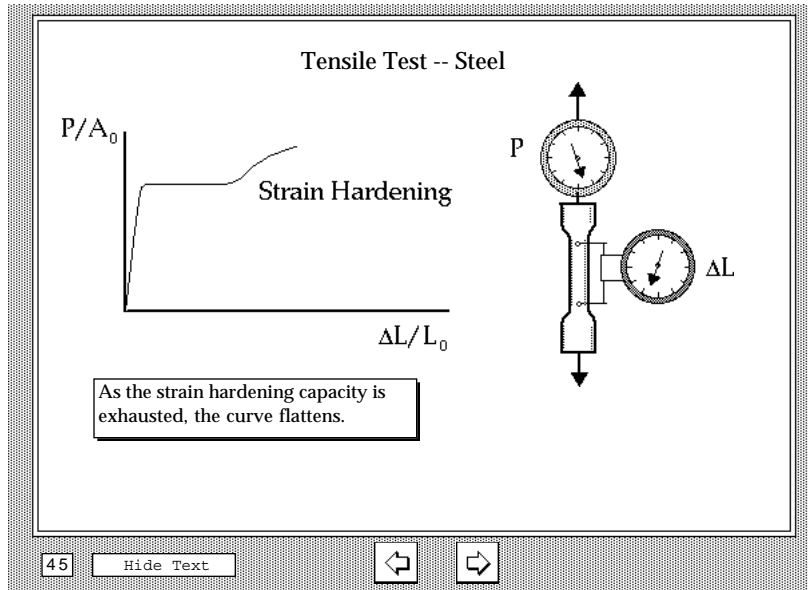
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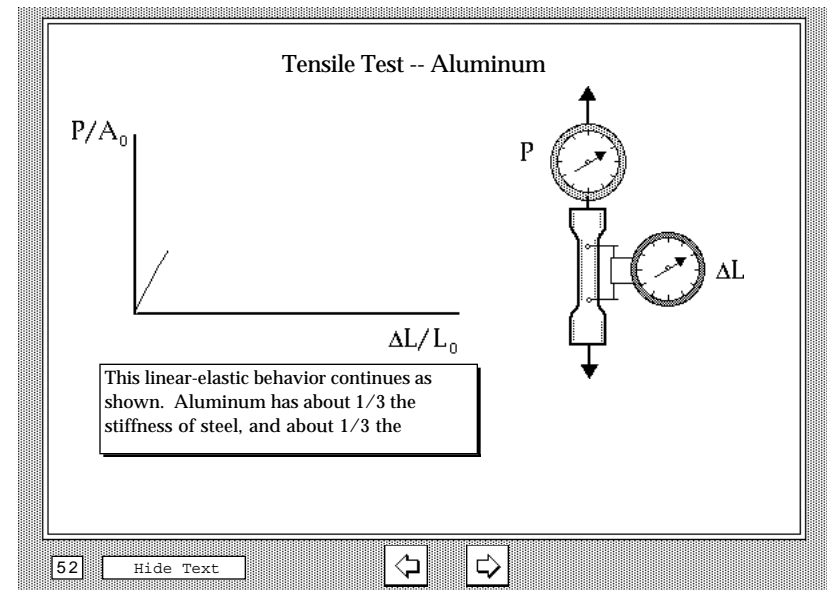
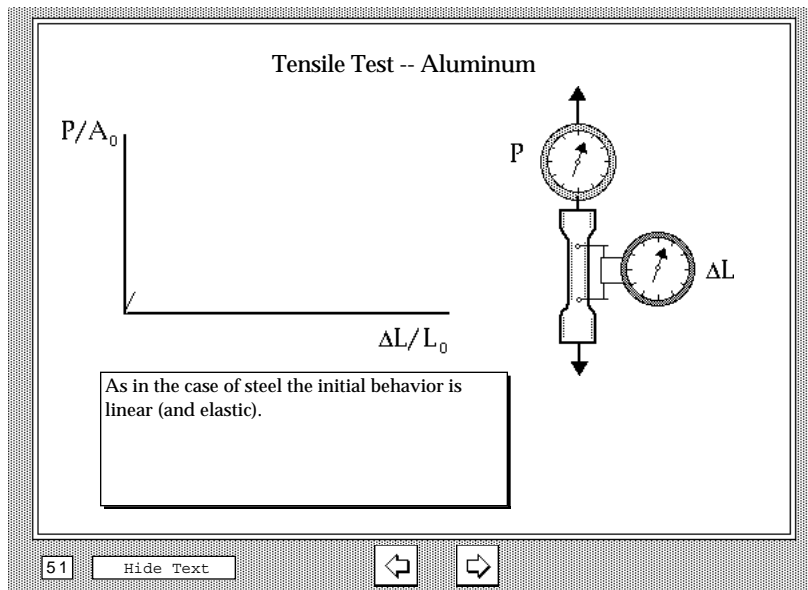
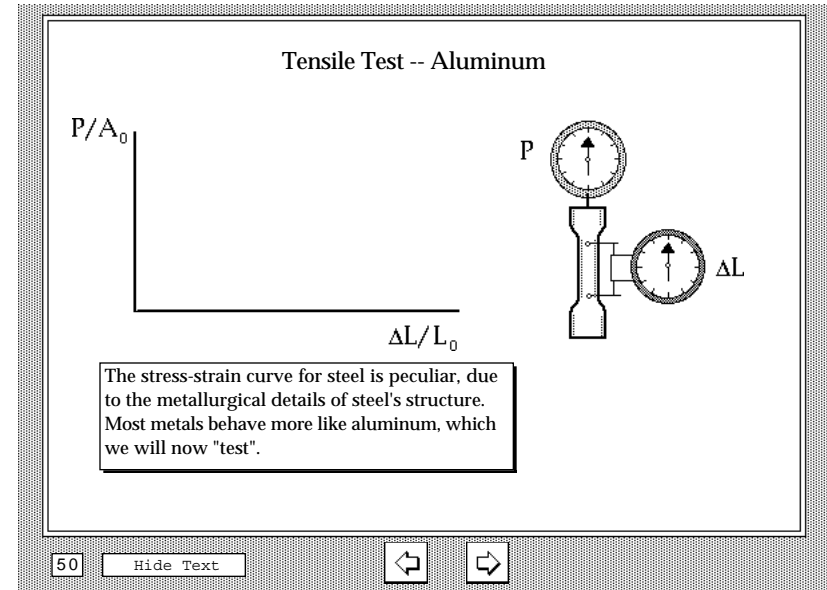
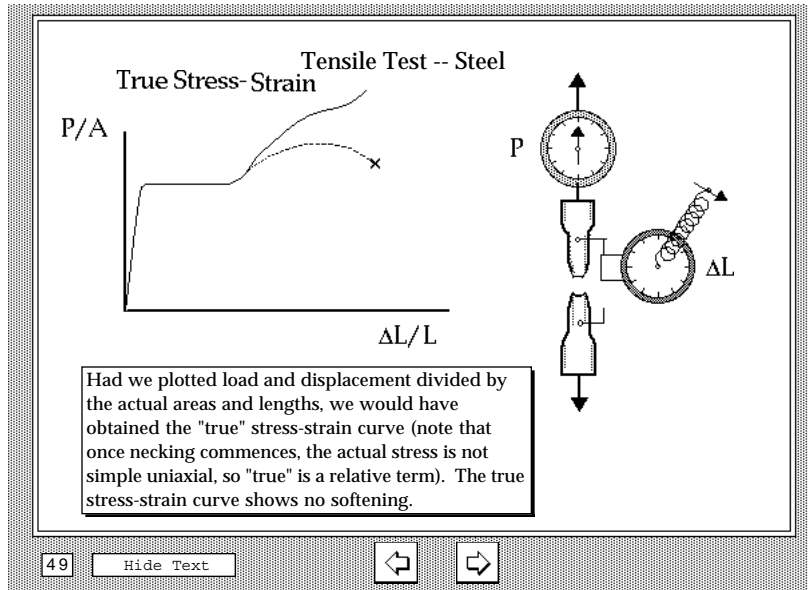
Tensile Test -- Steel



As the capacity for perfectly plastic deformation is used up, strain hardening begins. The deformations are still plastic, but increasing stresses are required.

44 Hide Text ↩ ➡





Tensile Test -- Aluminum

P/A_0

$\Delta L/L_0$

P

ΔL

As the load is increased the response becomes nonlinear and inelastic, but without the sharp break we saw in the case of steel.

53 Hide Text

Tensile Test -- Aluminum

P/A_0

$\Delta L/L_0$

P

ΔL

This behavior continues...

54 Hide Text

Tensile Test -- Aluminum

P/A_0

$\Delta L/L_0$

P

ΔL

...and continues...

55 Hide Text

Tensile Test -- Aluminum

P/A_0

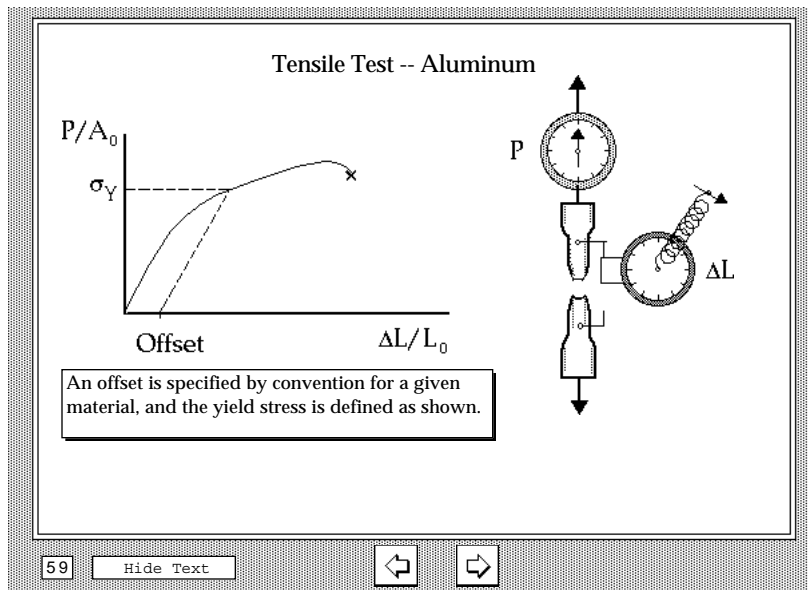
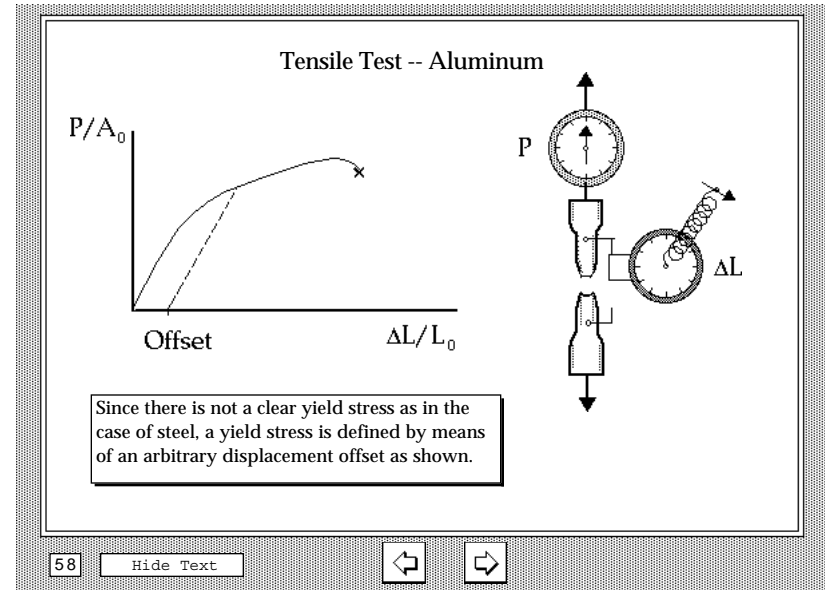
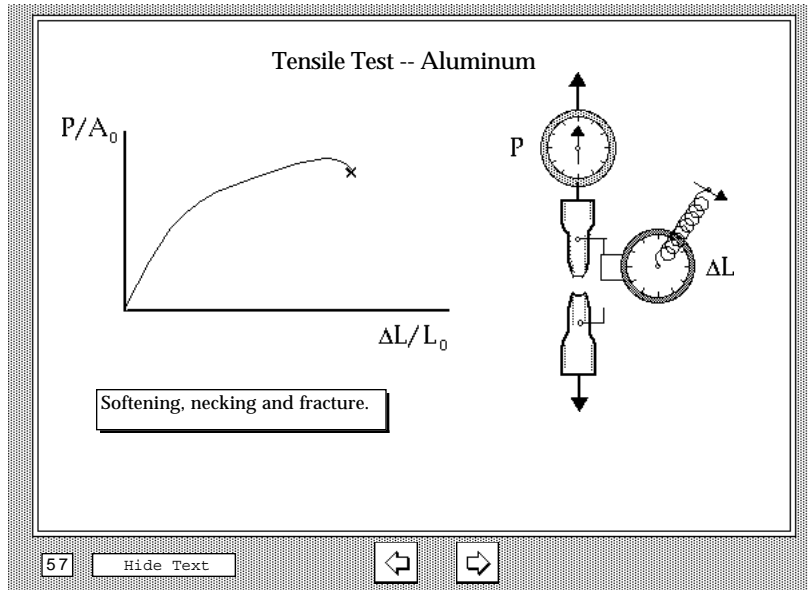
$\Delta L/L_0$

P

ΔL

...maximum load...

56 Hide Text



The End

60