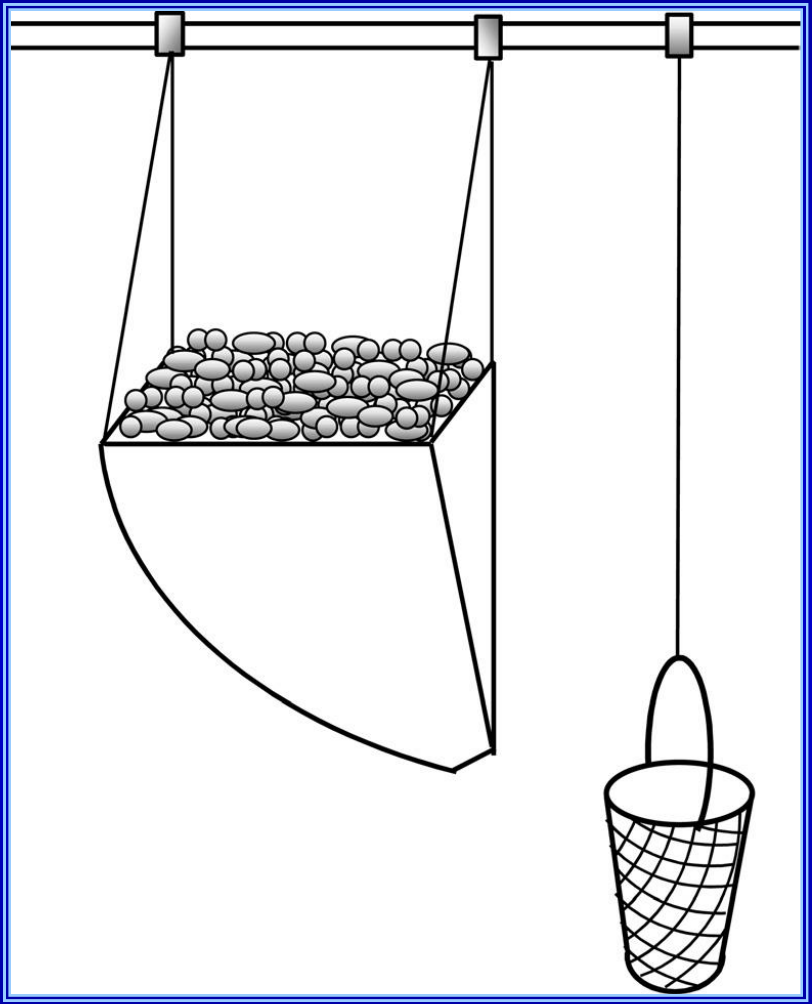
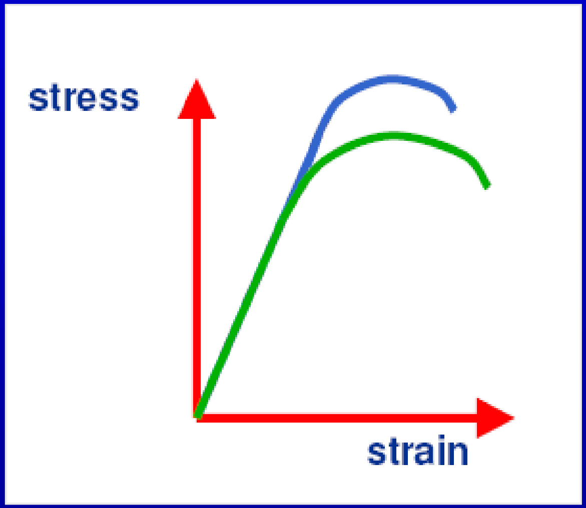
Tensile deformation and tensile test - I

- **Tensile test**
- **Tensile loading of monocrystal**
- **Plastic deformation**
- **True stress – true strain curve**

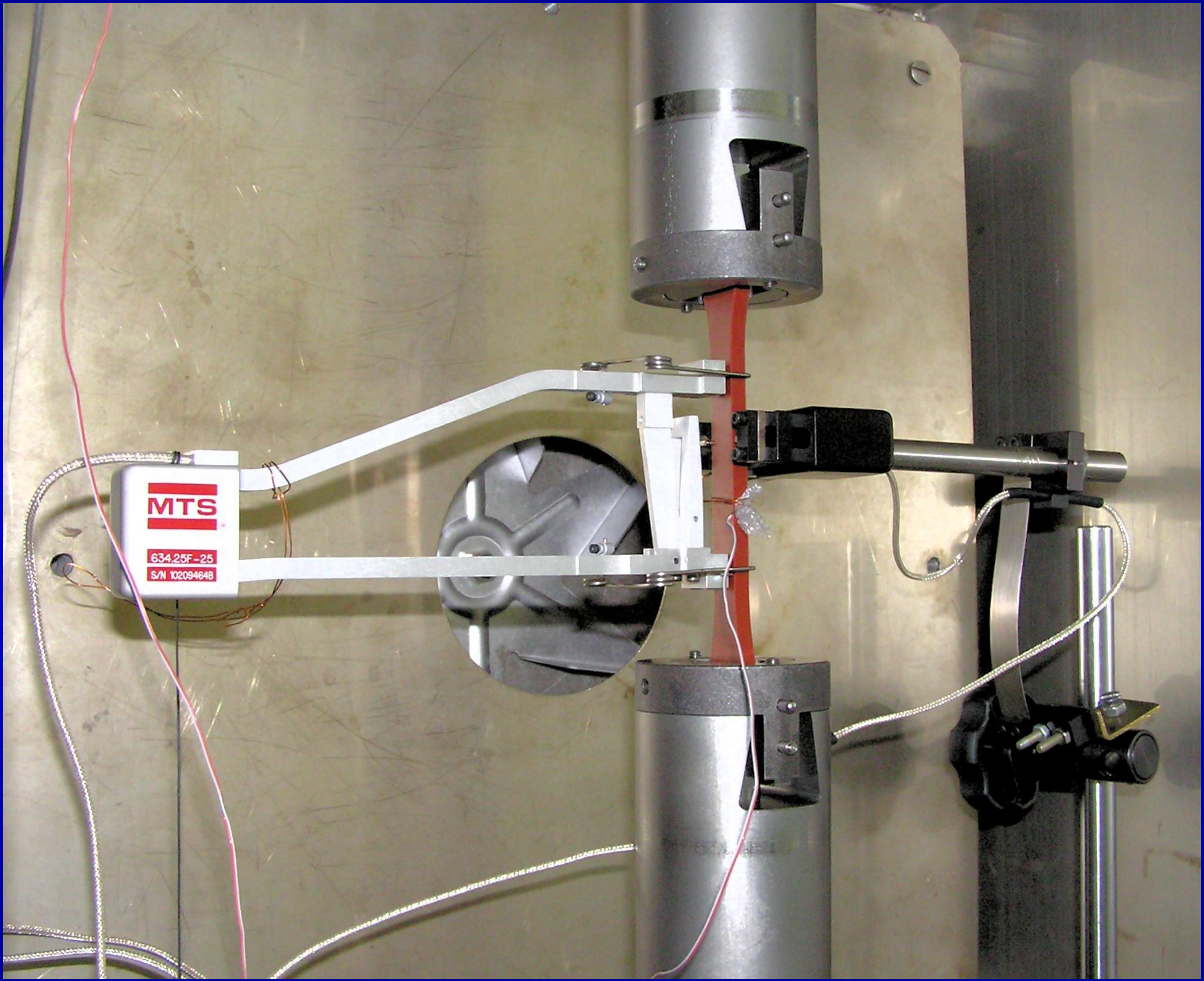
Tensile loading



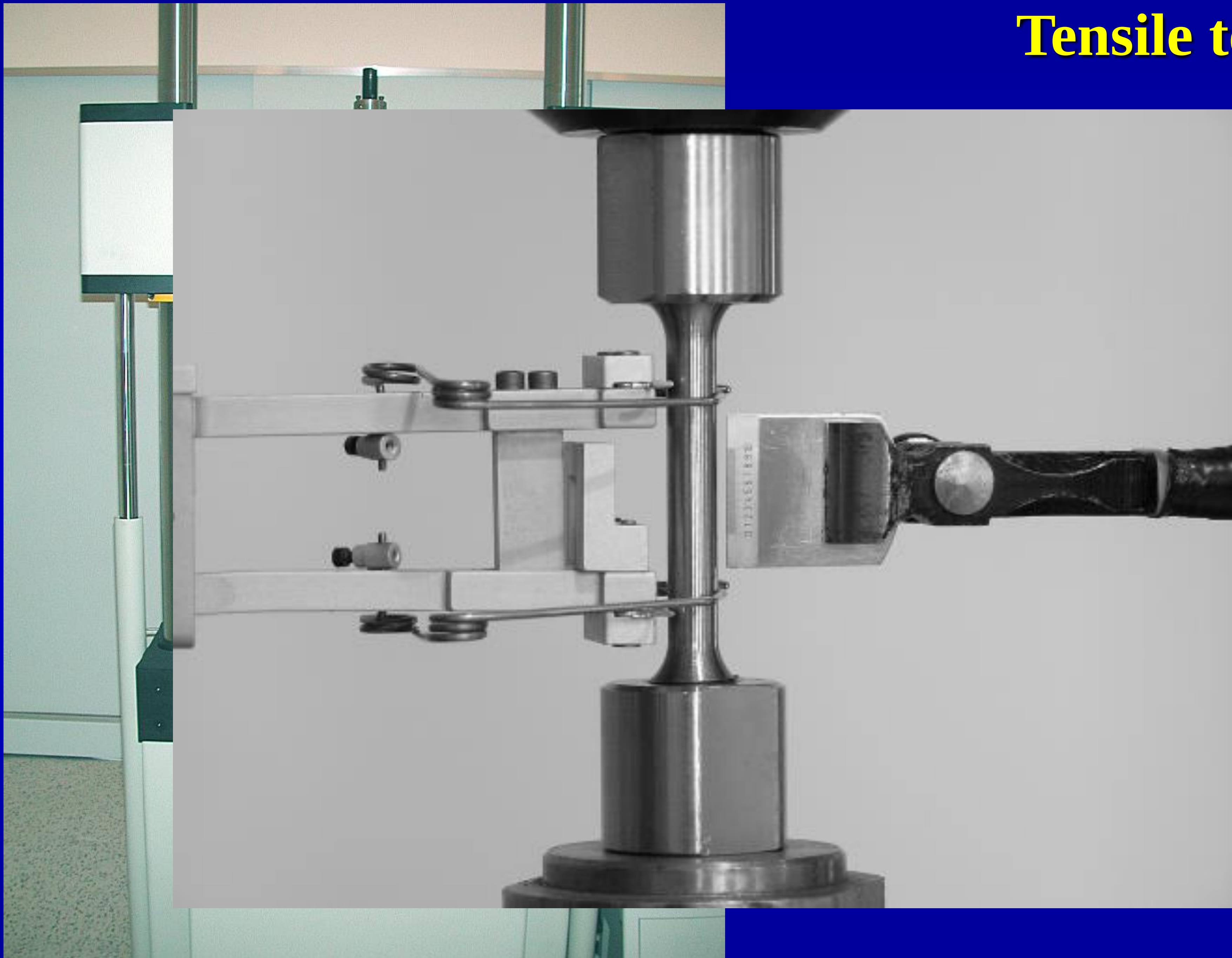
- Leonardo da Vinci tensile test of wires
- 15th century !

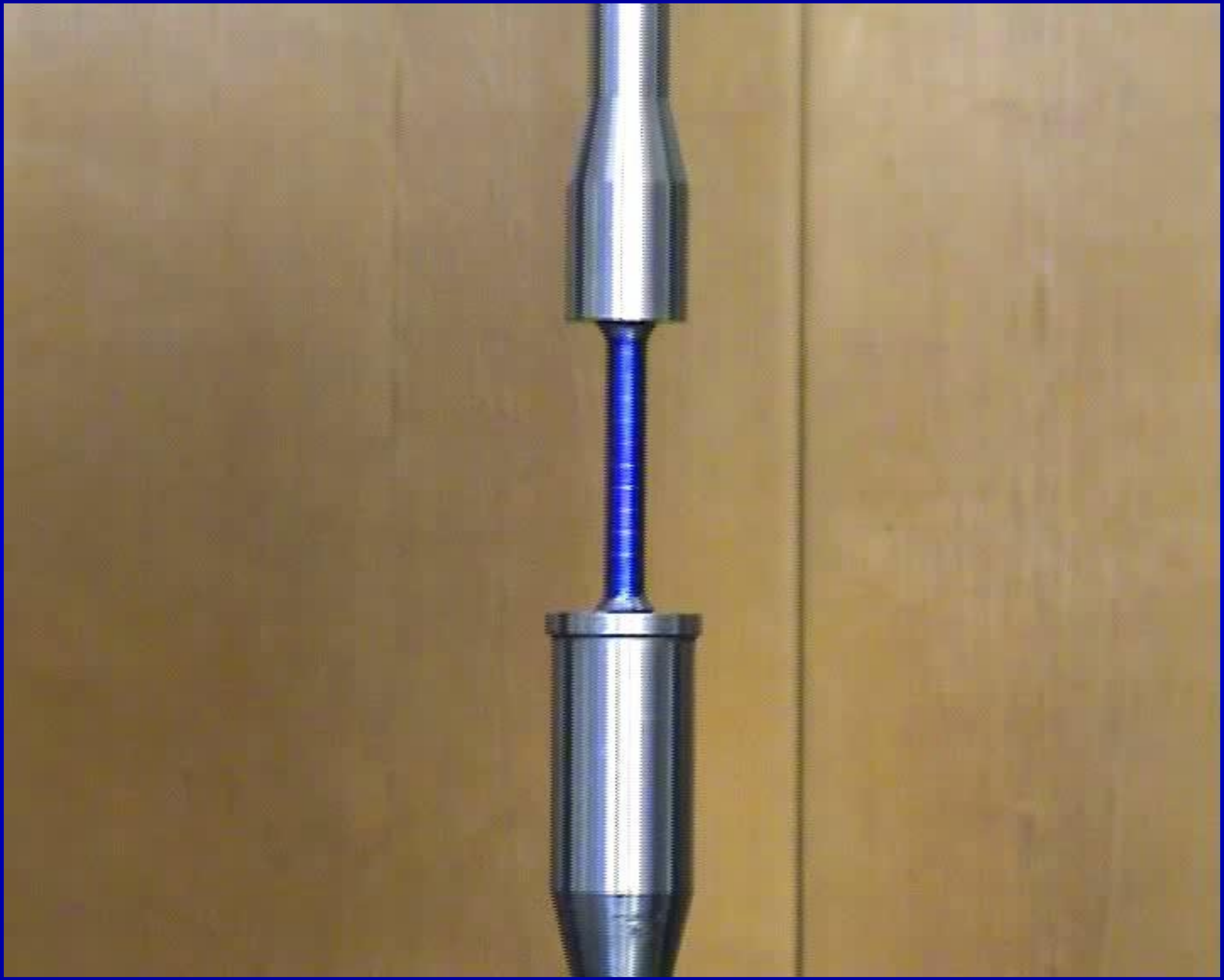


Tensile test



Tensile test





Metallic materials – tensile test at room temperature

Europe: (ČSN) EN 10 002 – 1 /2002

USA: ASTM E 8 – 01 (ASTM E8 M)

EN 10002 consists of 5 parts

part 1: Test method at room temperature (ČSN EN 10 002-1)

part 2: Verification of force measuring system for tensile test machines (ČSN EN 10 002-2)

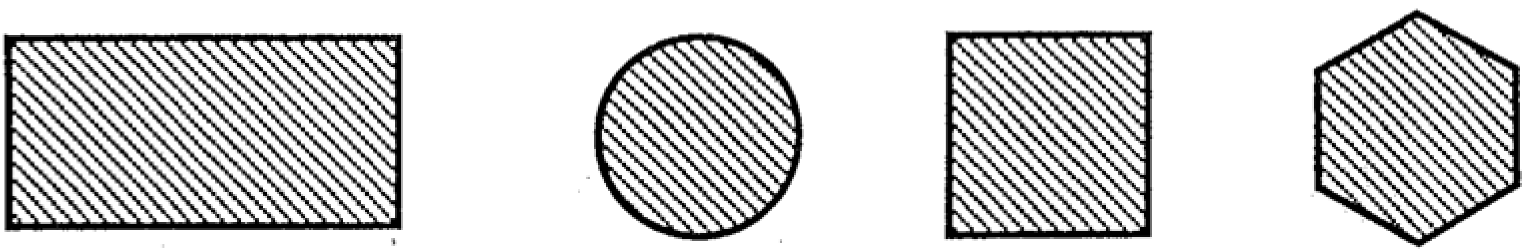
part 3: Calibration of load cells used for verification of test machines for tensile tests (ČSN EN 10 002-3)

part 4: Verification of extensometers used for ensile test (ČSN EN 10 002-4)

part 5: Test method at increased temperature (ČSN EN 10 002-5)

General guidelines for the test samples

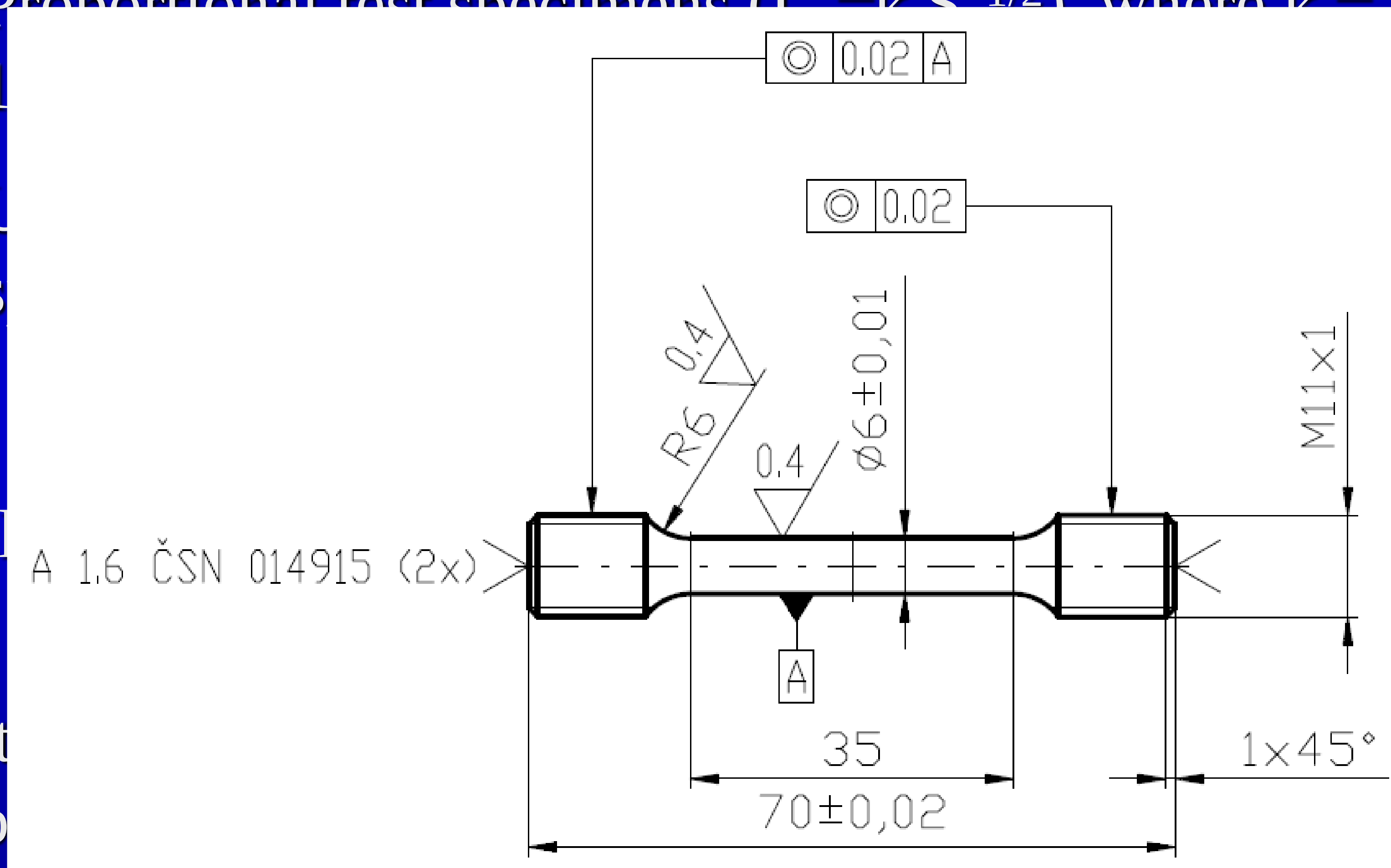
sheet metal	profiles, rods, wires	



thickness	typical dimension	gauge length
0.1 to 3 mm		A50; A80
	< 4 mm	A200; A100
3 mm and more	> 4 mm	A5.65; A11.3

General guidelines for the test samples

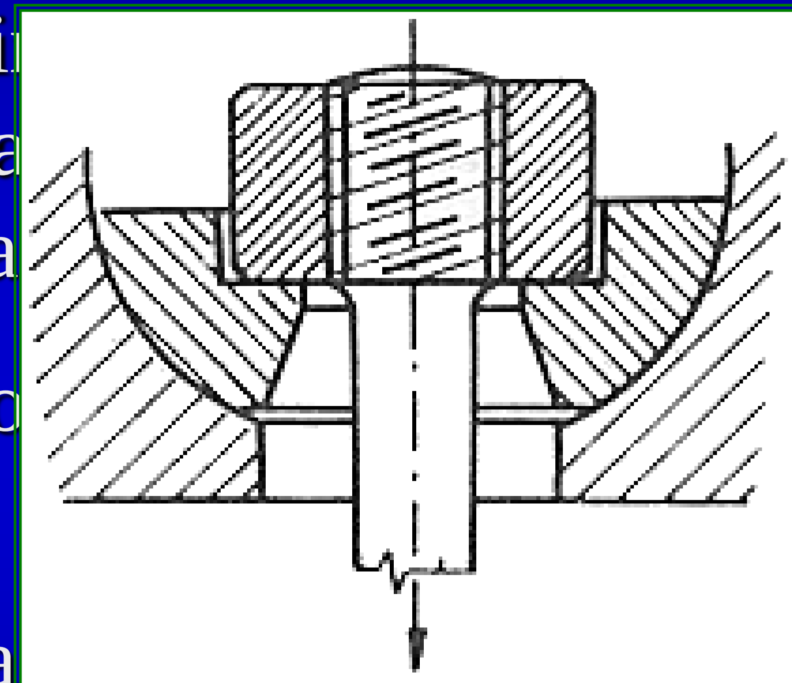
- Proportional test specimens (L =k S $^{1/2}$), where k =
  1
- U
  s



original
special

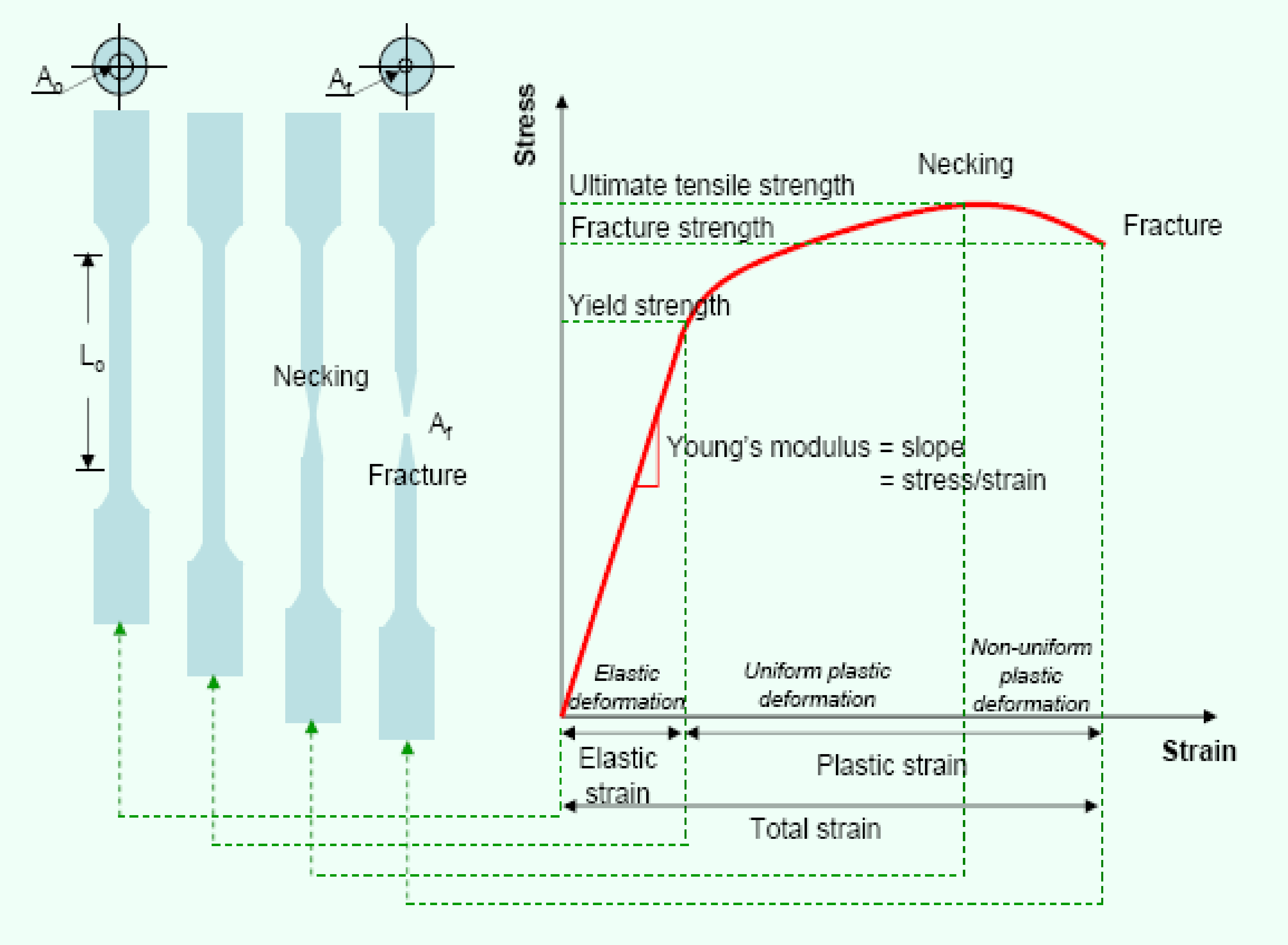
fabricat
effect o

General guidelines for the test procedure



- Loading axis of the machi… s (assured by cardan shaft, a… grips/fixture with spherica…
- Loading rate (according to… d to measure)
- Visual inspection and mea… specimen before the test, measurement of gauge length before the test.
- Speciment preloading gripped state before the test

Engineering stress-strain curve



Engineering tensile curve

load vs elongation trace

- stress characteristics R_e, R_m
- strain characteristics A, Z

Engineering tensile curve

Measuring the force (load) F

Calculation of engineering stress

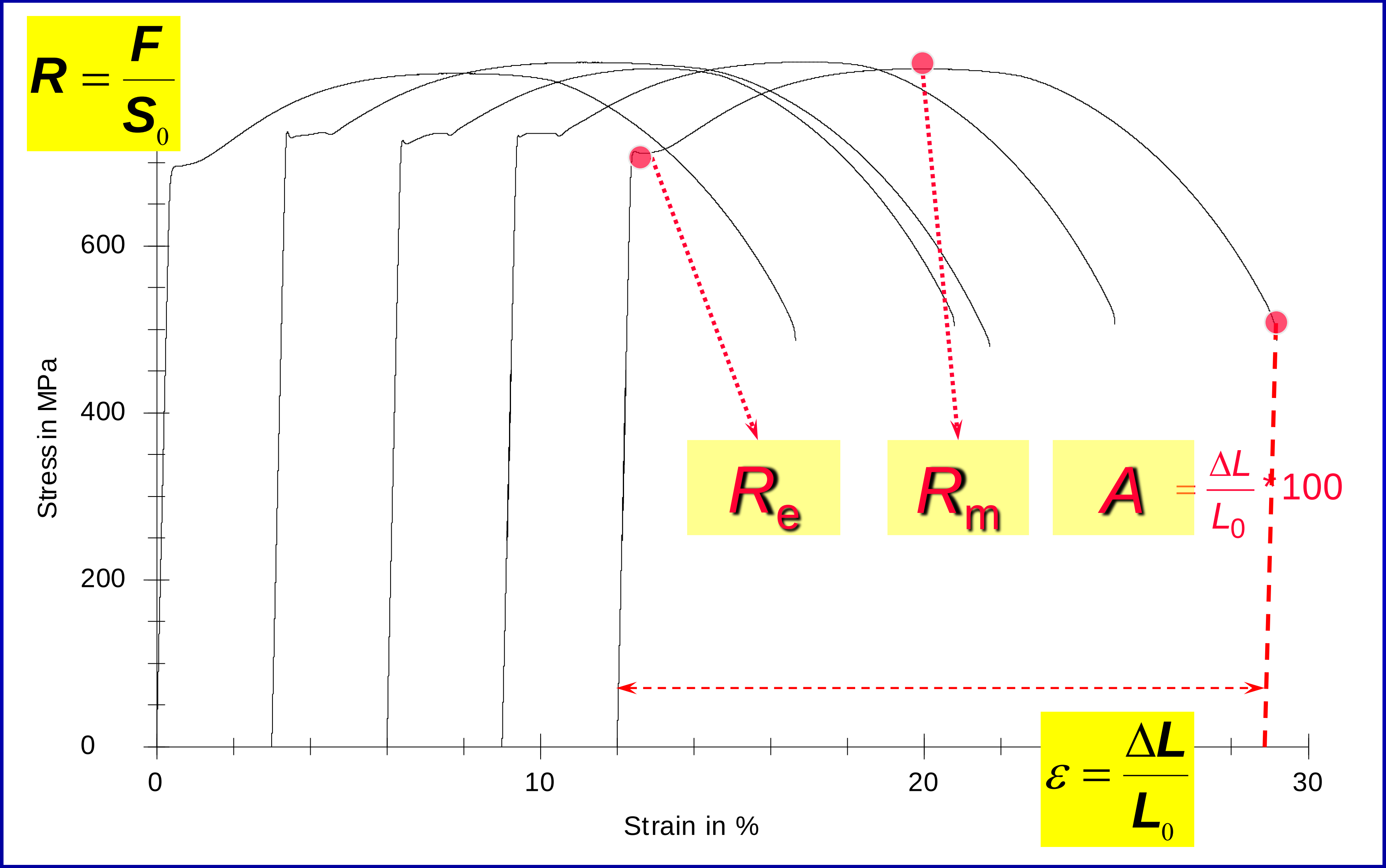
$$R = \frac{F}{S_0}$$

Measuring the relative elongation ΔL

Calculation of relative elongation

$$\varepsilon = \frac{\Delta L}{L_0}$$

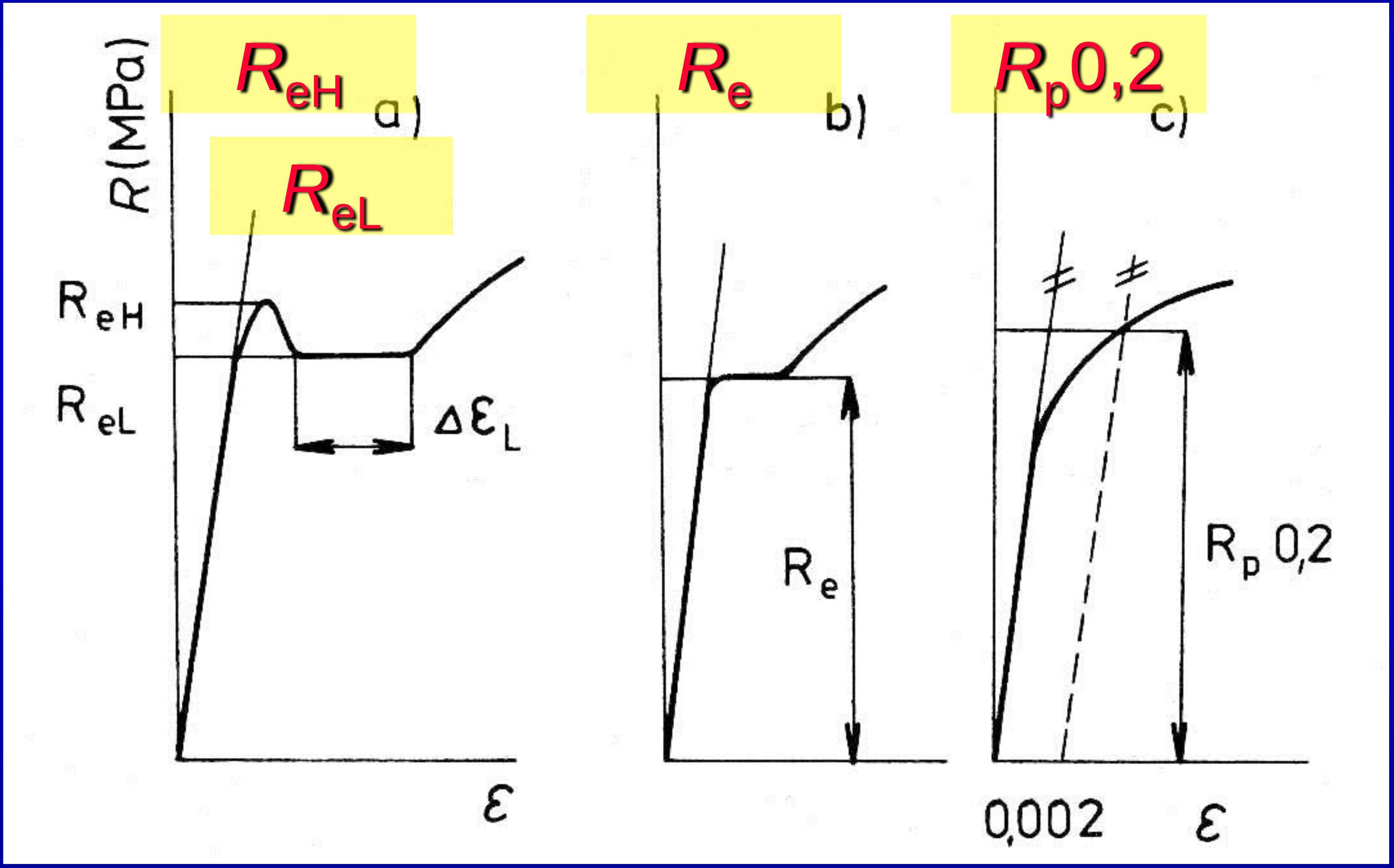
Tensile test



Tensile test

sp. nr.	S_0 [mm^2]	R_e [MPa]	R_m [MPa]	A_g [%]	A [%]	E (t) [GPa]	E (s) [GPa]	μ [-]
1	28,29	695,5	806,9	7,49	16,40	206,0	196,0	0,287
2	28,30	722,6	812,8	6,64	14,53	210,3	196,0	0,296
3	28,28	730,0	820,0	7,67	18,46	222,4	196,0	0,295
4	28,29	733,0	820,5	7,37	15,70	204,0	195,7	0,299
5	28,29	711,9	812,5	7,64	16,94	188,6	196,0	0,304

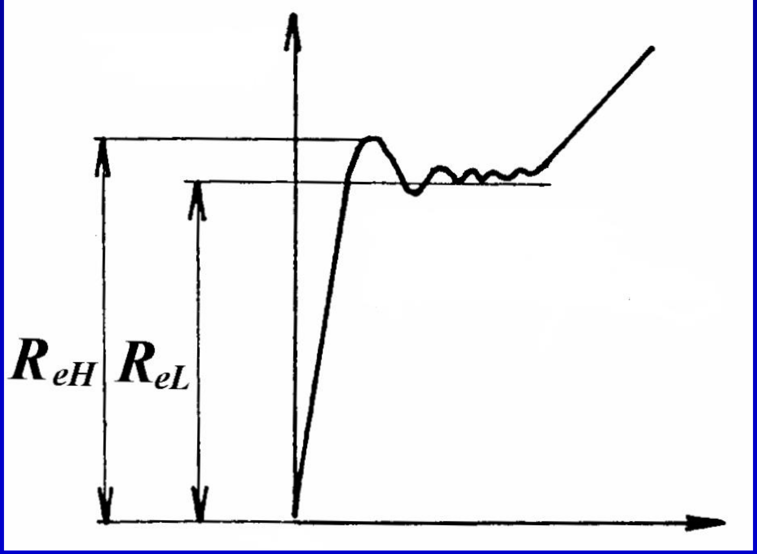
determining the yield strength or proof stress

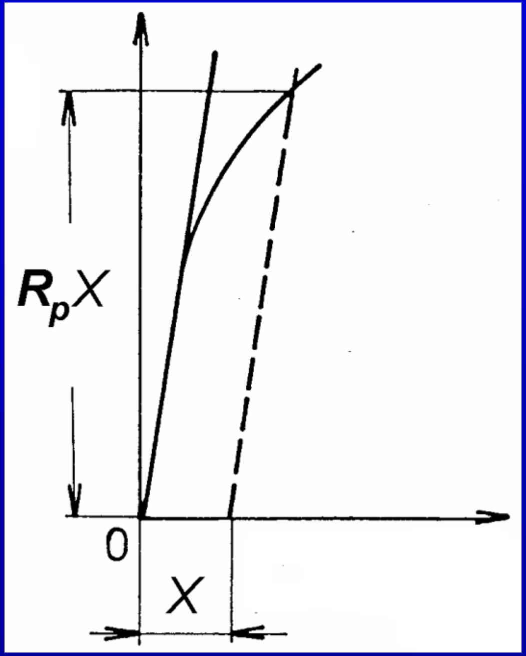


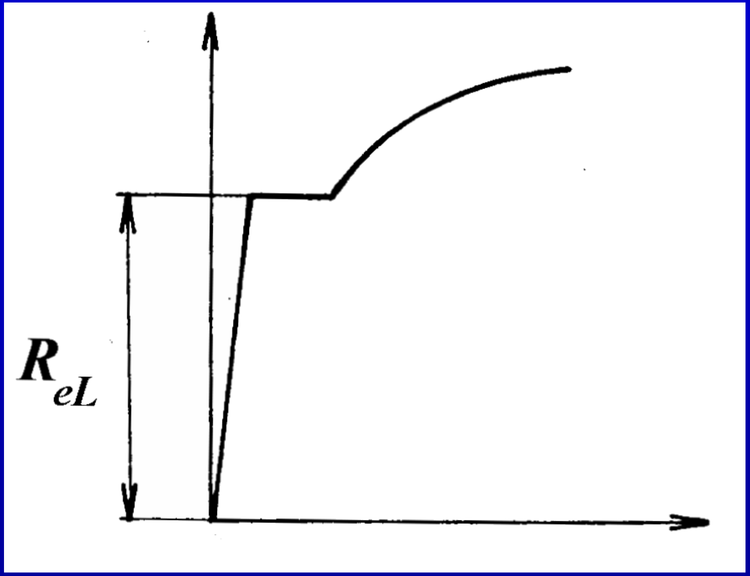
Proof stress

- ***p*** = plastic deformation
- ***t*** = total deformation
- ***r*** = remanent deformation

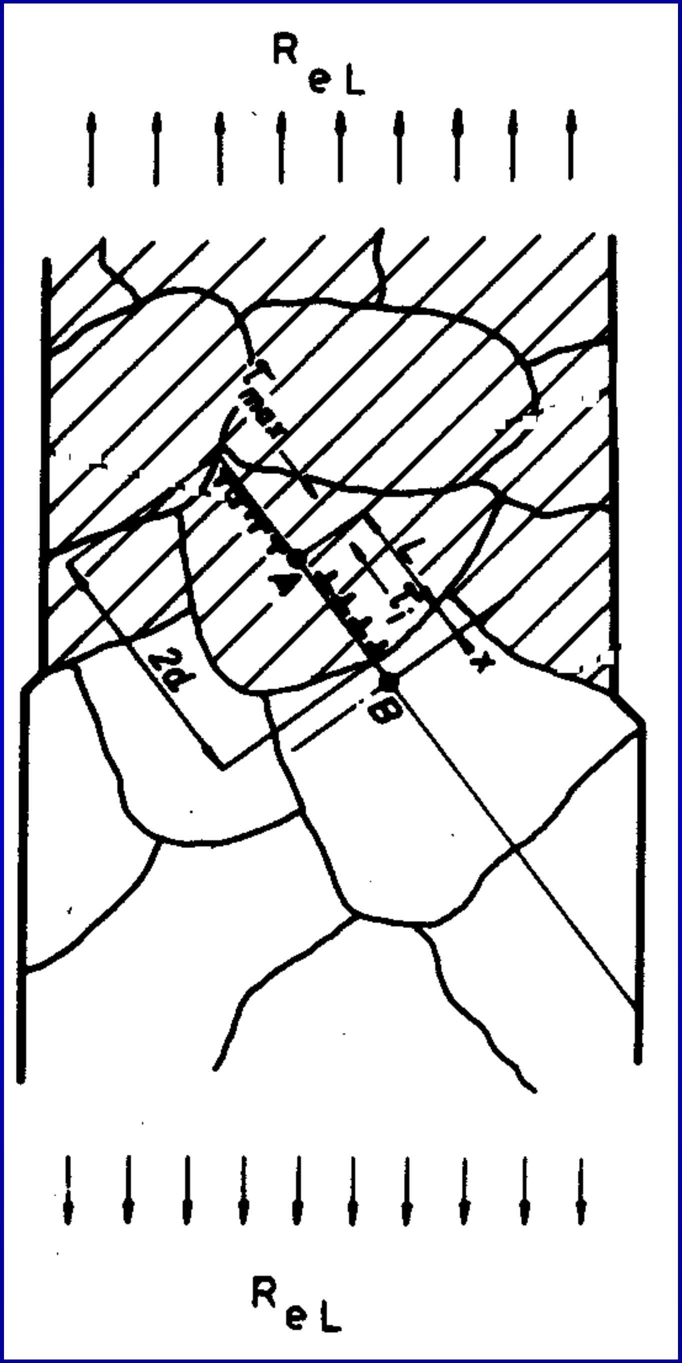
Tensile test

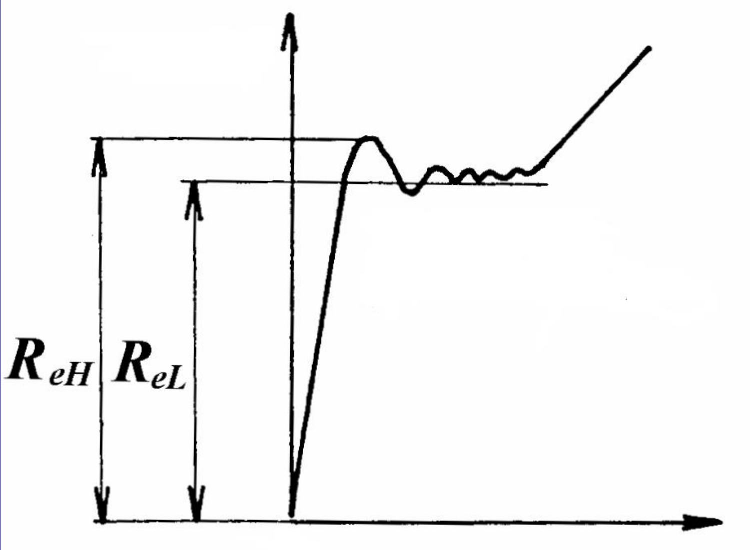






Tensile diagram of polycrystal





$$R_{eL} = \sigma_i + k.d^{-1/2}$$

Hall - Petch relation

Steels designation (upper/lower yield stress)

Weldable steels

S185	S235	S275	S355

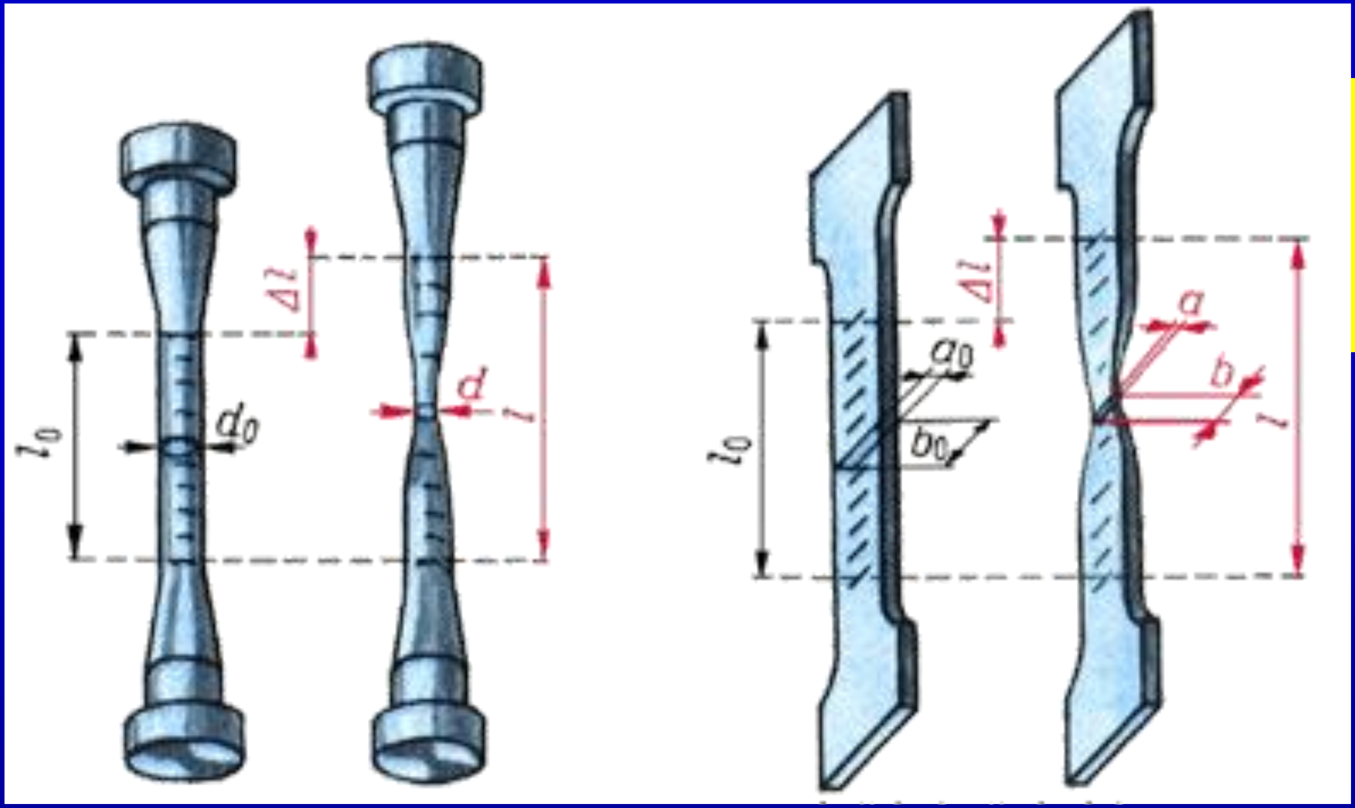
Machinable steels

E295	E335	E360

Deformation characteristics

- contraction

$$Z = \frac{S_0 - S_u}{S_0} 100[\%]$$



EN ISO 2566 (420308)

- Transferability for ductility for carbon and low carbon steels

$$k^{I} = \frac{L_0^{I}}{\sqrt{S_0^{I}}}, k^{II} = \frac{L_0^{II}}{\sqrt{S_0^{II}}}$$

$$\frac{A^{II}}{A^{I}} = \left(\frac{k^{I}}{k^{II}}\right)^{0,4}$$

Nechť k^I = 5,65, k^{II} =11,3 pak platí $A_{11,3}$=$A_{5,65}$.0,759)

Energetic characteristics

- Metals / standard tensile diagram

Resilience (resilience modulus): material characteristics quantifying energz unit in volume unit loaded under stress of *Re*. Deformation energy which can be accumulated

$$w_{el} = \frac{R_e^2}{2E}\left[MPa = \frac{MN.m}{m^2.m} = \frac{MJ}{m^3}\right]$$

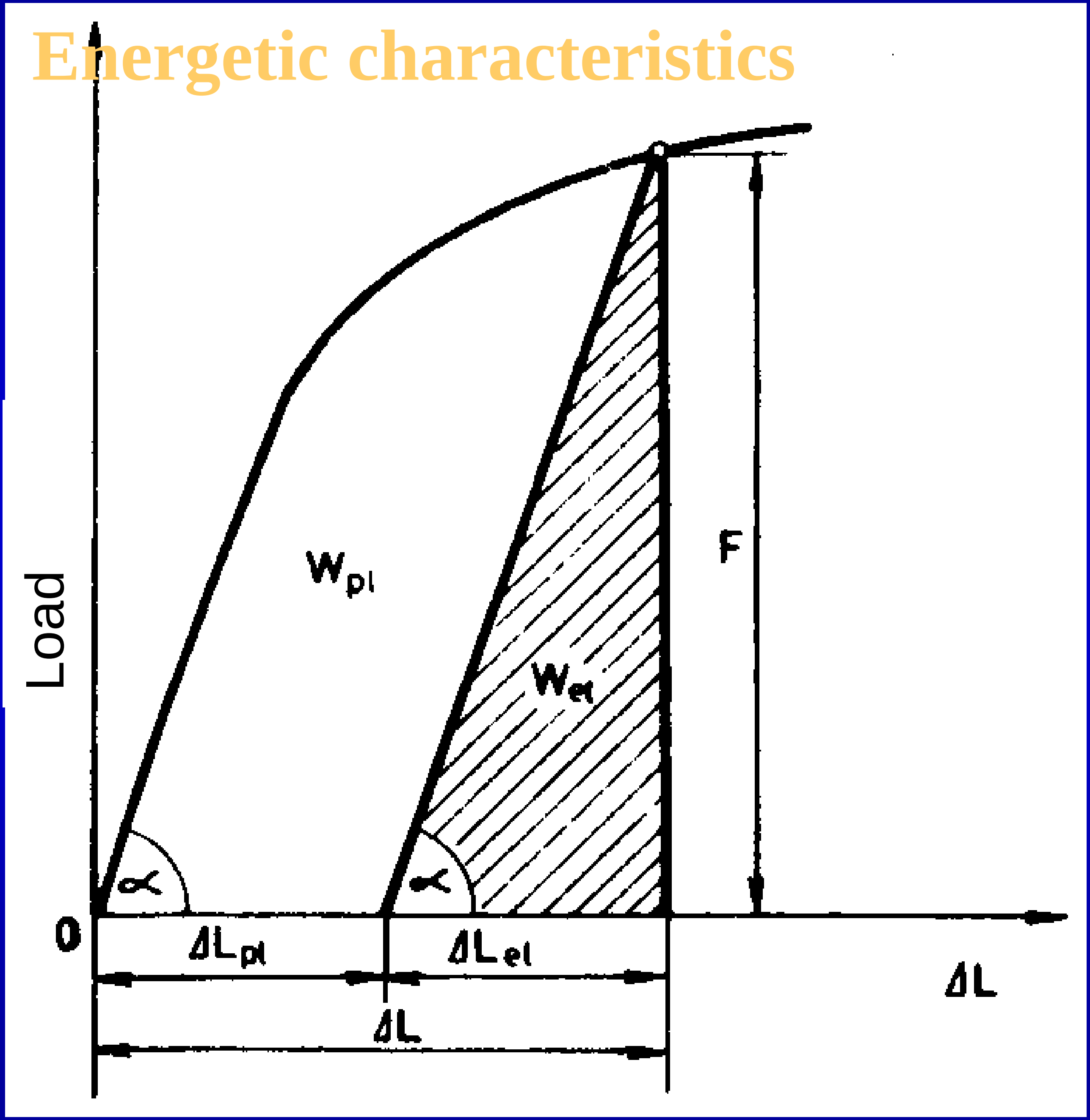
Brittle materials

$$w_f = \frac{R_m + R_e}{2} \cdot \frac{A}{100}\left[\frac{MJ}{m^3}\right],$$

$$w_f = \frac{2}{3} R_m \cdot \frac{A}{100}\left[\frac{MJ}{m^3}\right]$$

Tensile toughness (toughness modulus) energy needed for materials fracture

Energetic characteristics



Metallic materials – strain hardening

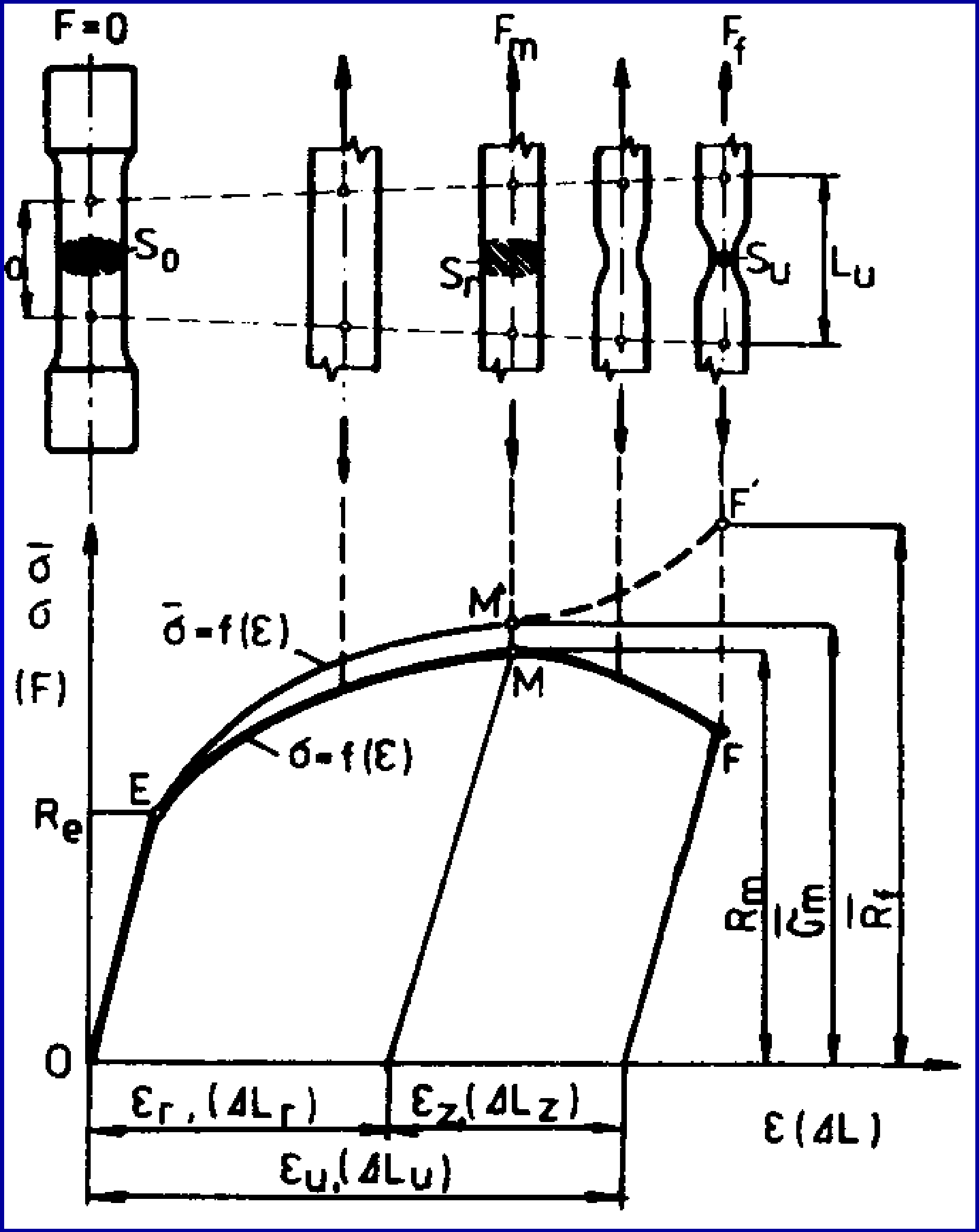
- Metal – engineering diagram diagram
- Proportional to Rm to Re ratio

$$\frac{R_m}{R_e} \geq 1{,}4 \text{.........} \, high\_hardening$$

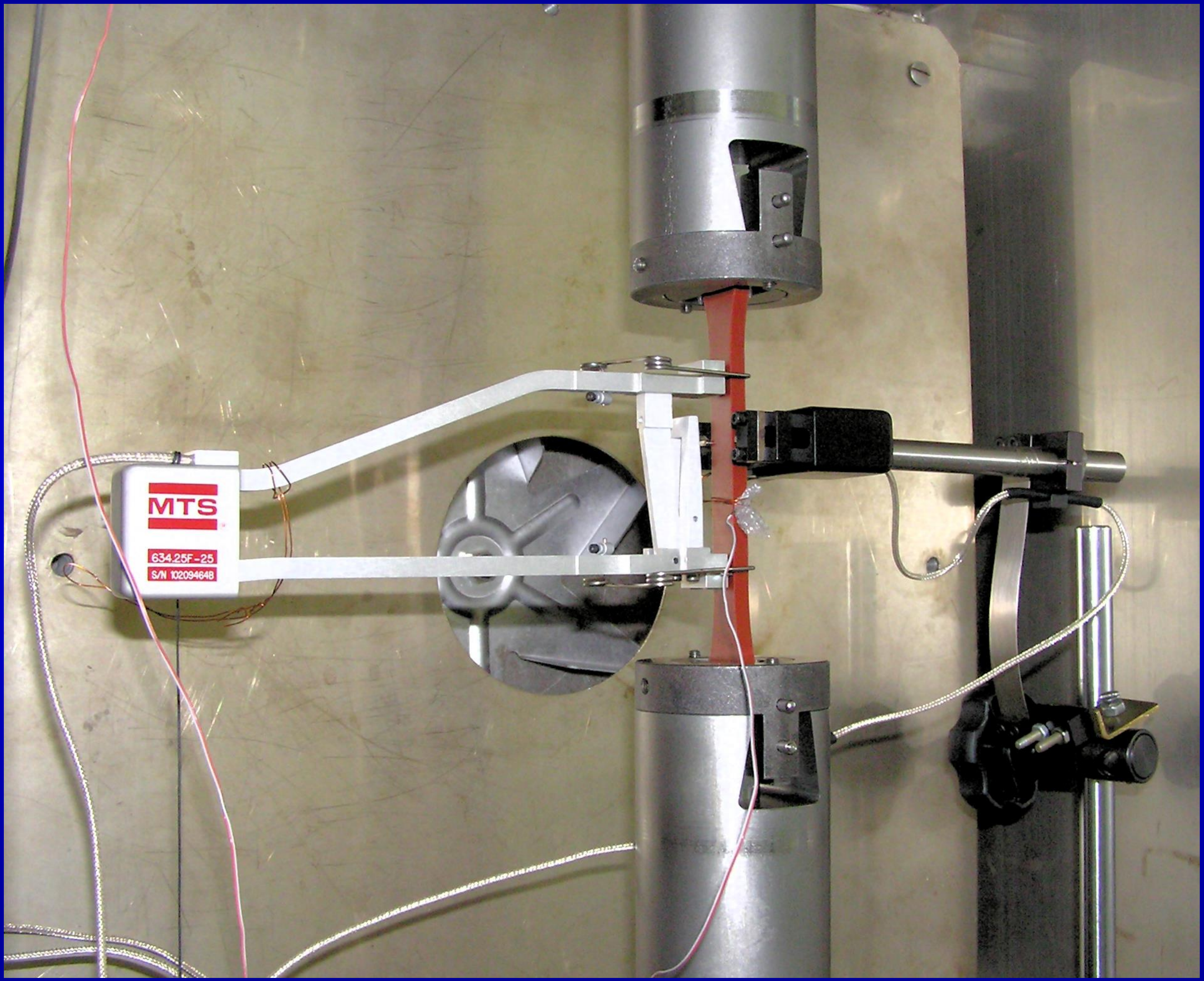
$$\frac{R_m}{R_e} \leq 1{,}2 \text{.........} \, small\_hardening$$

Tensile test

engineering stress –
engineering strain

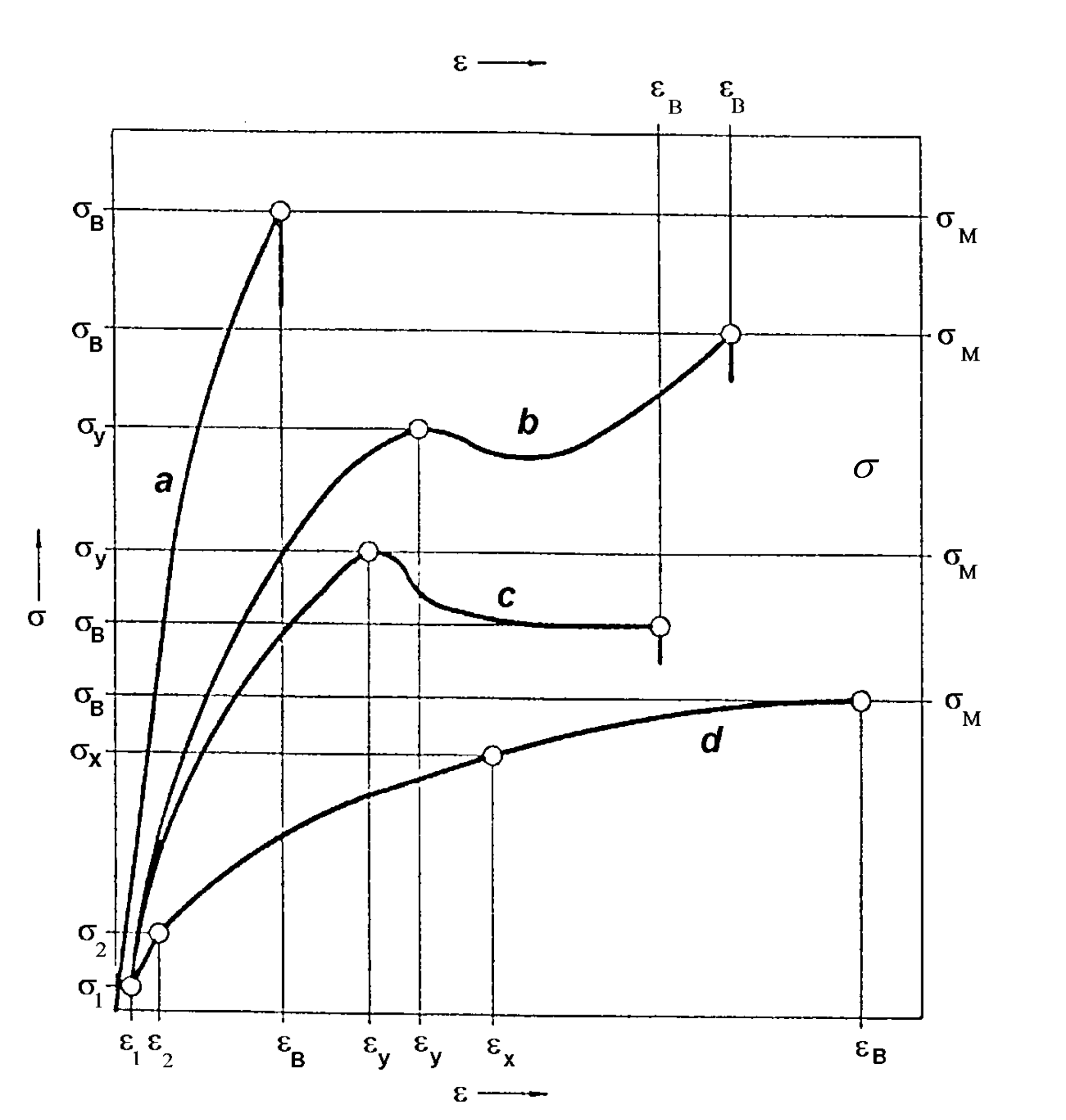


Tensile test - plastics



Tensile test / plastics

Plastics – EN ISO 527



σ_M - tensile strength

σ_y – yield stress

σ_B – yield stress

a - brittle

b – ductile with σ_y

C – ductile with σ_y

D – ductile without σ_y

Tensile test - ceramics

EN 658

- limited machinability - simple geometry
- high brittleness – premature fracture
- susceptibility to loading axis alignment

- preference to flexural test



Energetic characteristics

- energie accumulated during damage

EN 658-1 (Cumulative damage energy)

Mechanical properties of ceramic composites at room temperature – based on tensile test data

$$\Phi = \frac{1}{S_0 L_0} \int_0^{\Delta L_f} F d(\Delta L) \left[\frac{kJ}{m^3} \right]$$

Engineering tensile diagram

$F - \Delta L$ $R - \varepsilon$

- Evaluation of the materials quality
- Purchase and sale (technickal delivery conditions
- Accidents analysis
- Strength calculations (fatigue)
- basic materials properties –material databases