

Toughness/crack resistance

- i. Basic notations (transition fracture behaviour of steels, temperature dependence of strength properties, fractography and failure analysis – basic approach)
- ii. **(Empirical) tests of toughness/crack resistance (Charpy, Pellini diagram, NDTT)**
- iii. **Linear – elastic fracture mechanics – LEFM (Irwin, fracture toughness tests), Elastic – plastic fracture mechanics EPFM (tests, interpretation)**

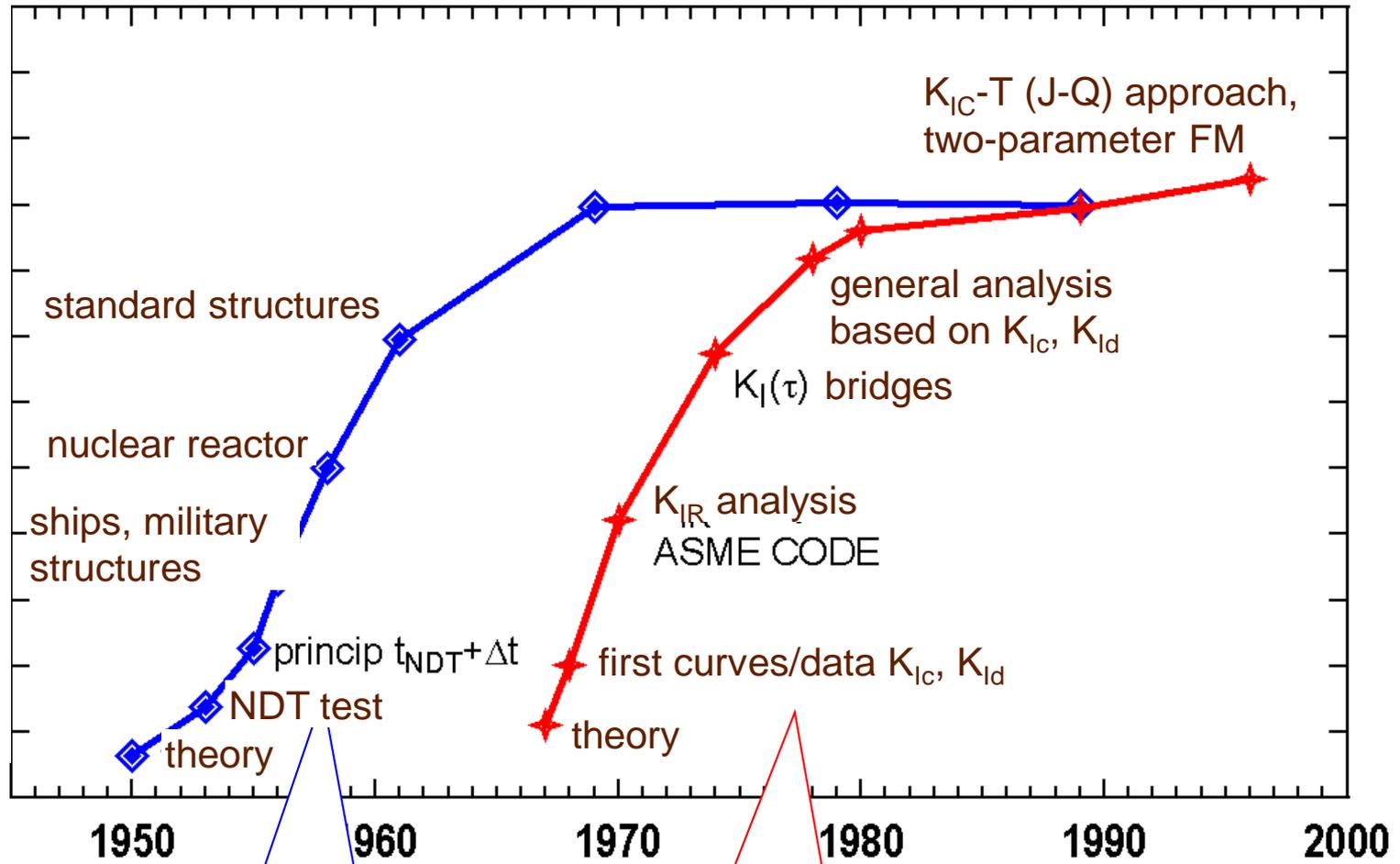
**Transition fracture behaviour –
change of the fracture
morphology, micromechanism,
impact energy**

**How to avoid catastrophic fracture of the
component**

**- crack arrest philosophy - concept of transition
temperature**

**- crack initiation prevention - fracture
mechanics concept**

Technological progress



Crack arrest concept

Crack initiation prevention

tests

- *comparative*
- *specific*

Main demands on comparative tests:

- ✓ Cheap production of test samples
- ✓ Simple procedures
- ✓ High reproducibility of tests

Philosophy of transition temperatures

- can be used for materials having transition behaviour of fracture
- transition behavior is taken as material property

operation temperature >> transition temperature



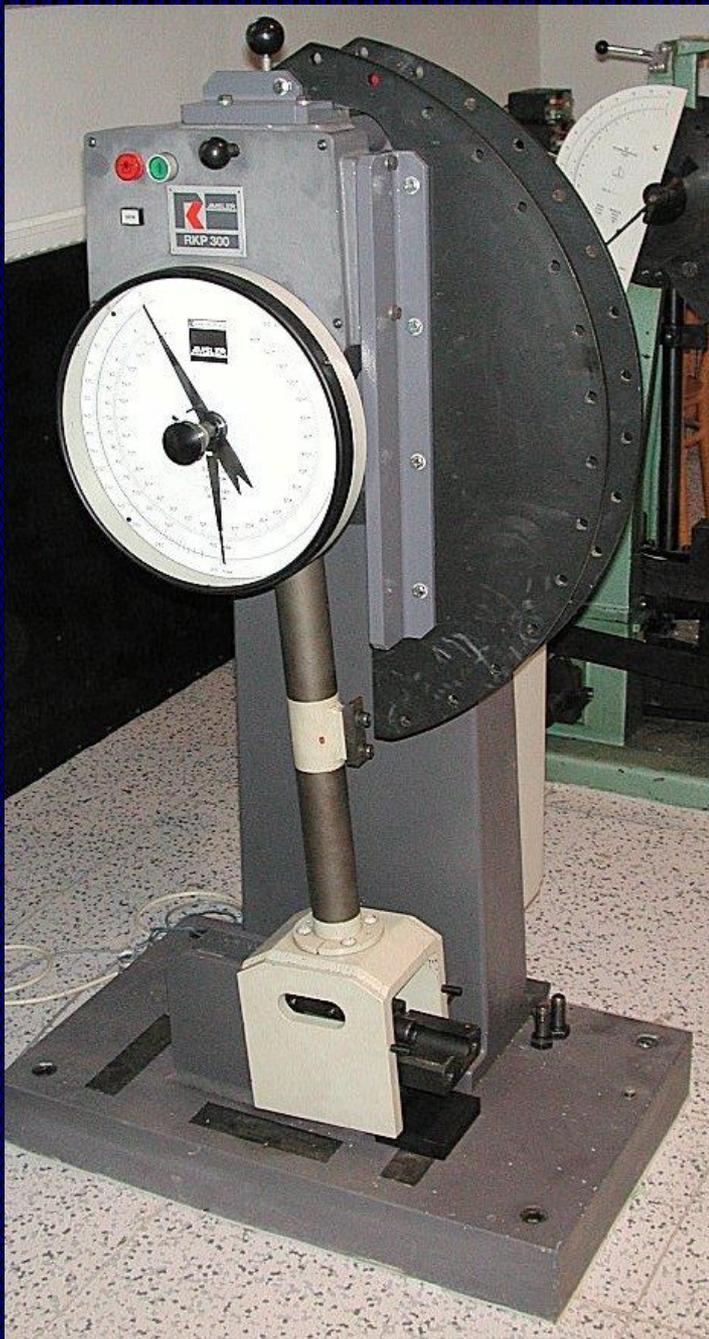
Charpy impact test

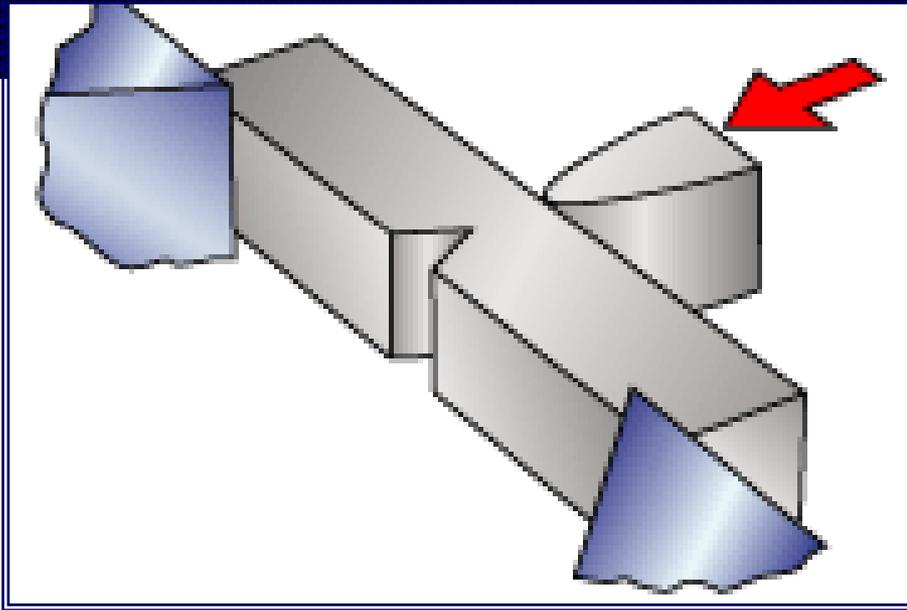
EN 10 045 – 1 (420381)

**Metallic materials – impact flexural
test according to Charpy**

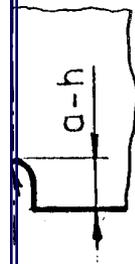
**Test machine – impact pendulum (50J) 150 J,
300 J, 450 J**

calibration - geometry, friction, weight of
pendulum
- calibration samples

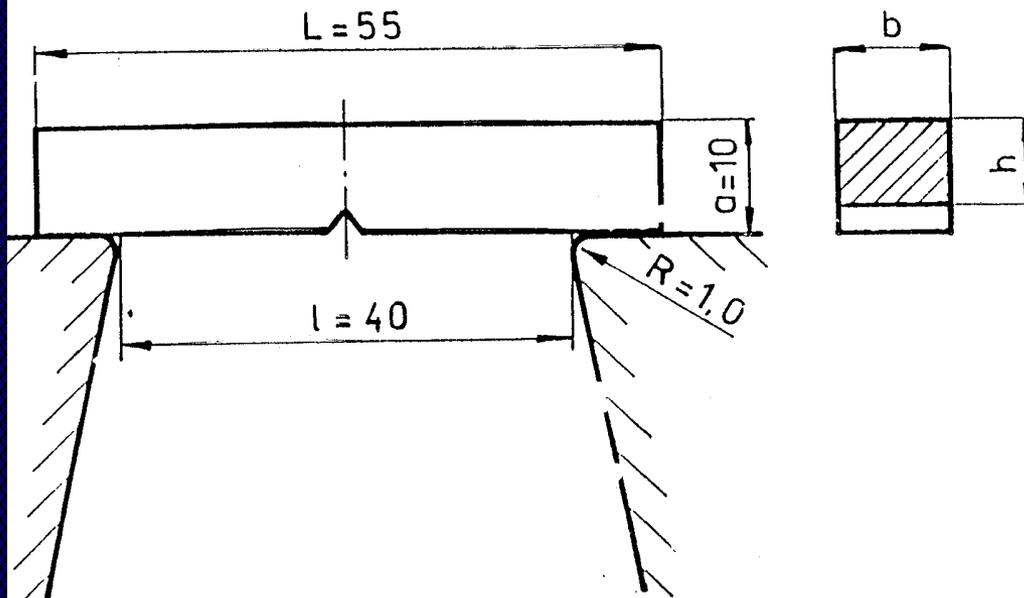




vrub



V notch
U notch



Impact test

What we are measuring during the test

300 J

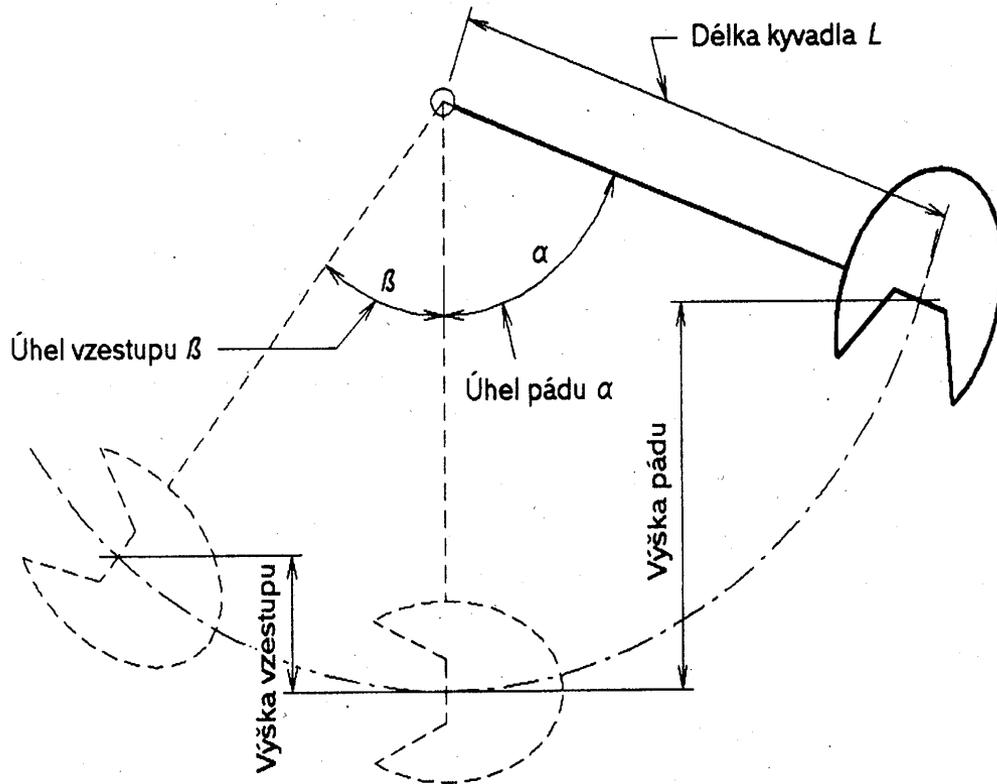
V-notch

Sample thickness 10 mm

KV = 121 J

KV150/7,5 = 83 J

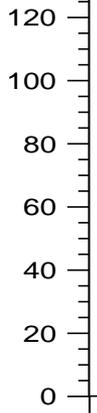
- ❖ test temperature
- ❖ fracture morphology
- ❖ FATT ($t_{50\%}$)
- ❖ other transition temperatures



What we are measuring during the test

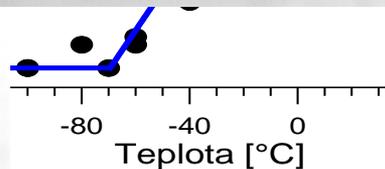
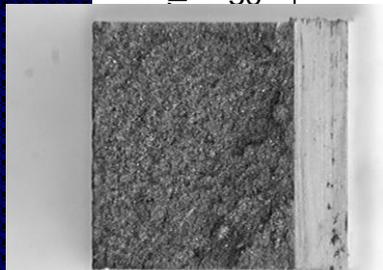
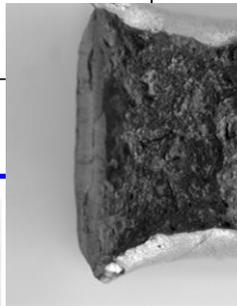
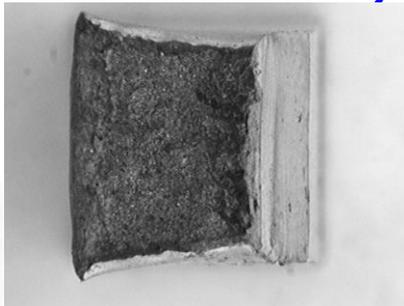
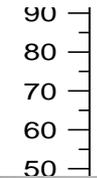
KV [J]

Nárazová práce [J]



% duct.fr.

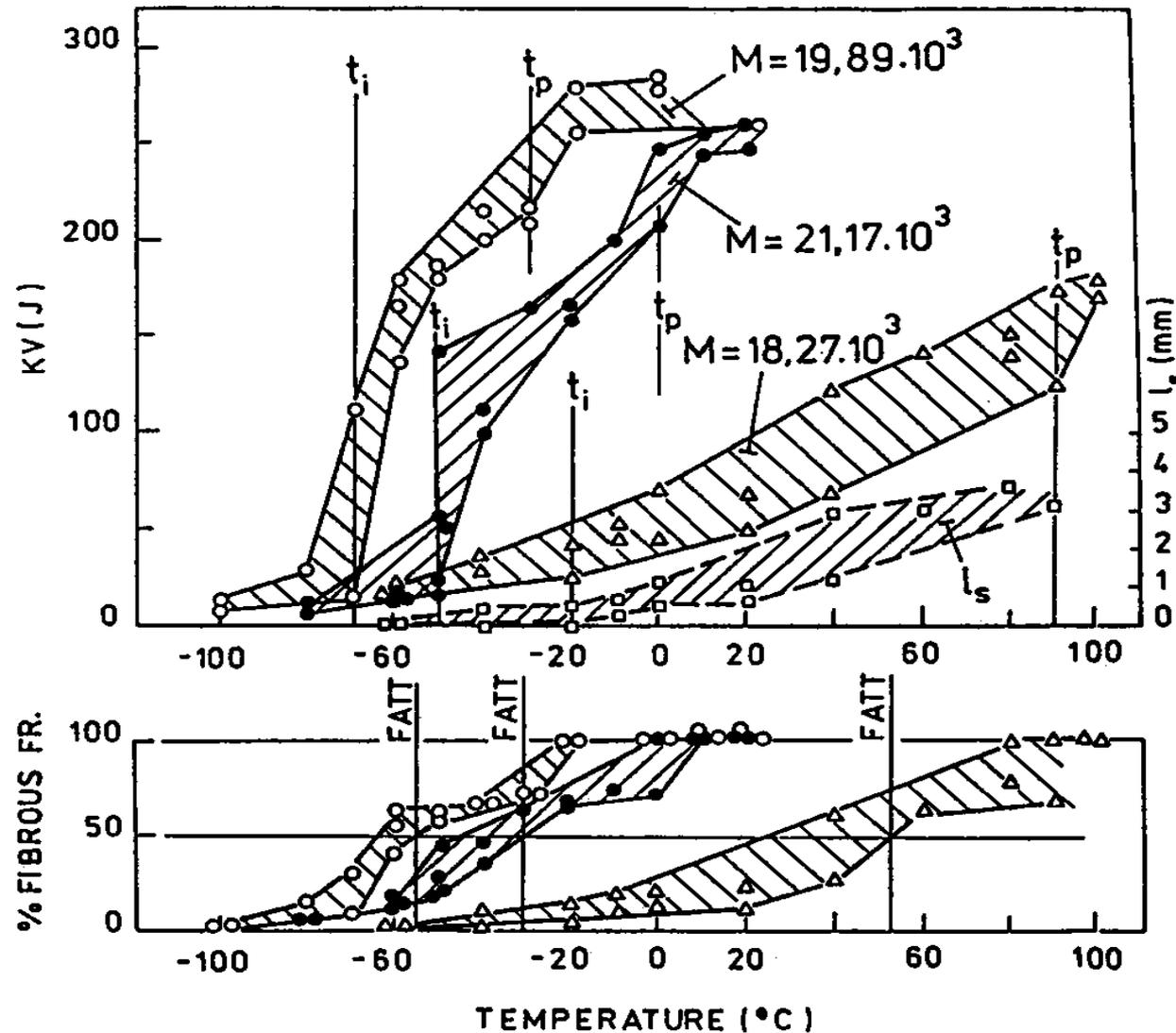
úhlu porušení



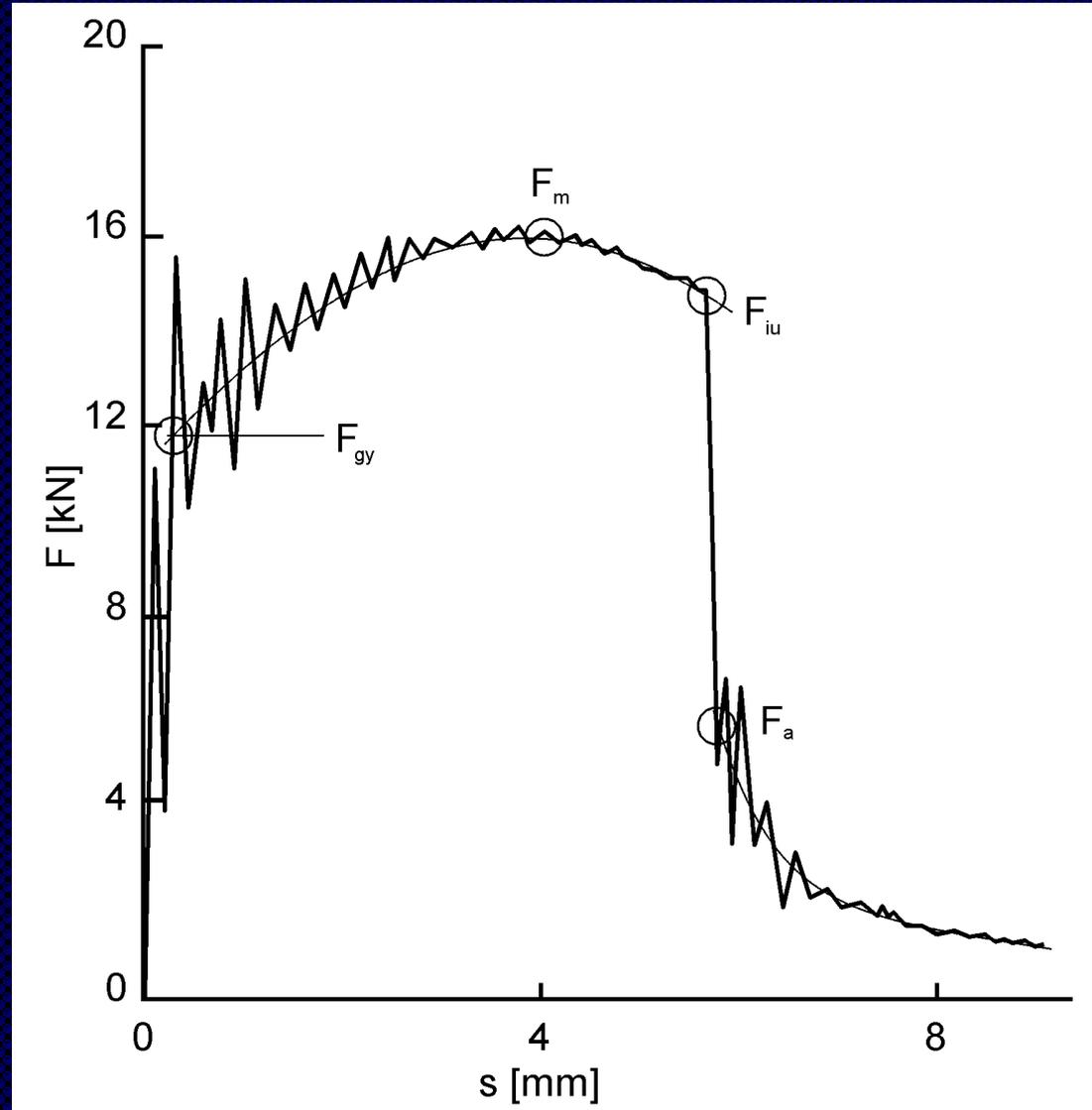
°C



Transition behaviour of KV with ageing



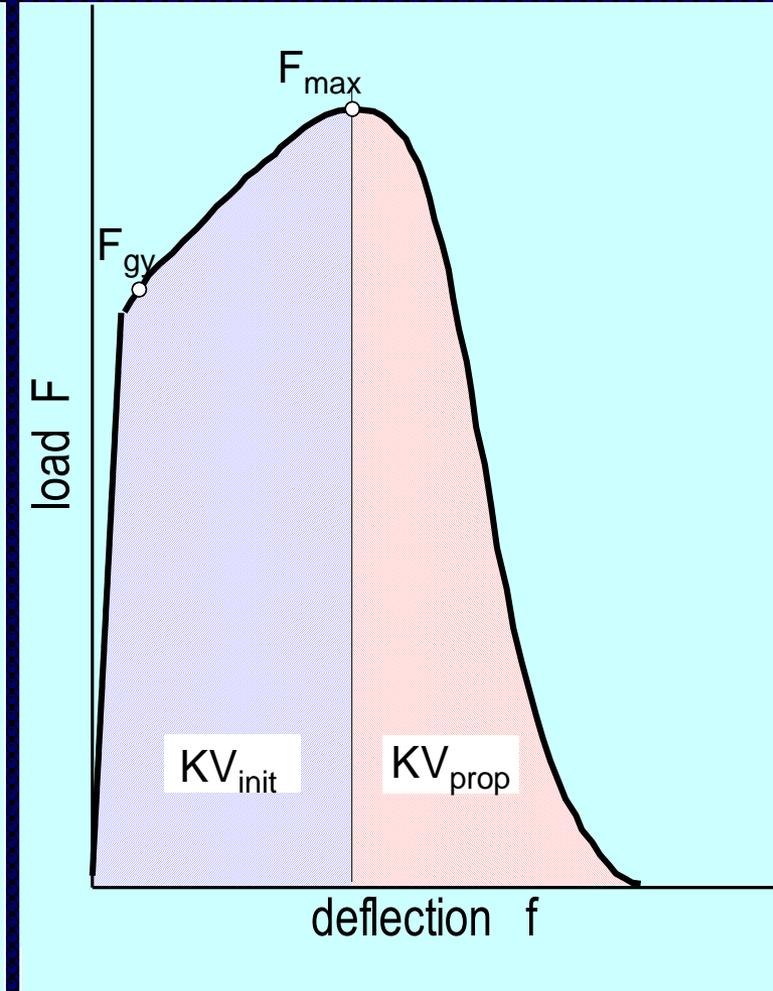
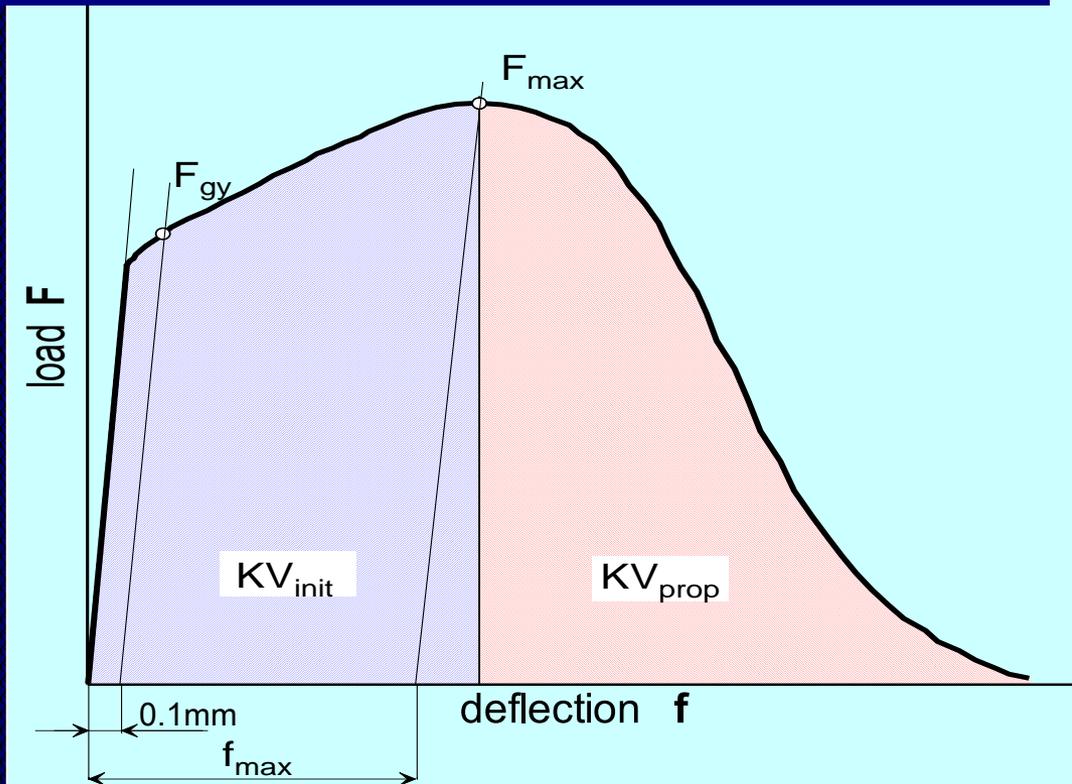
Impact test instrumented



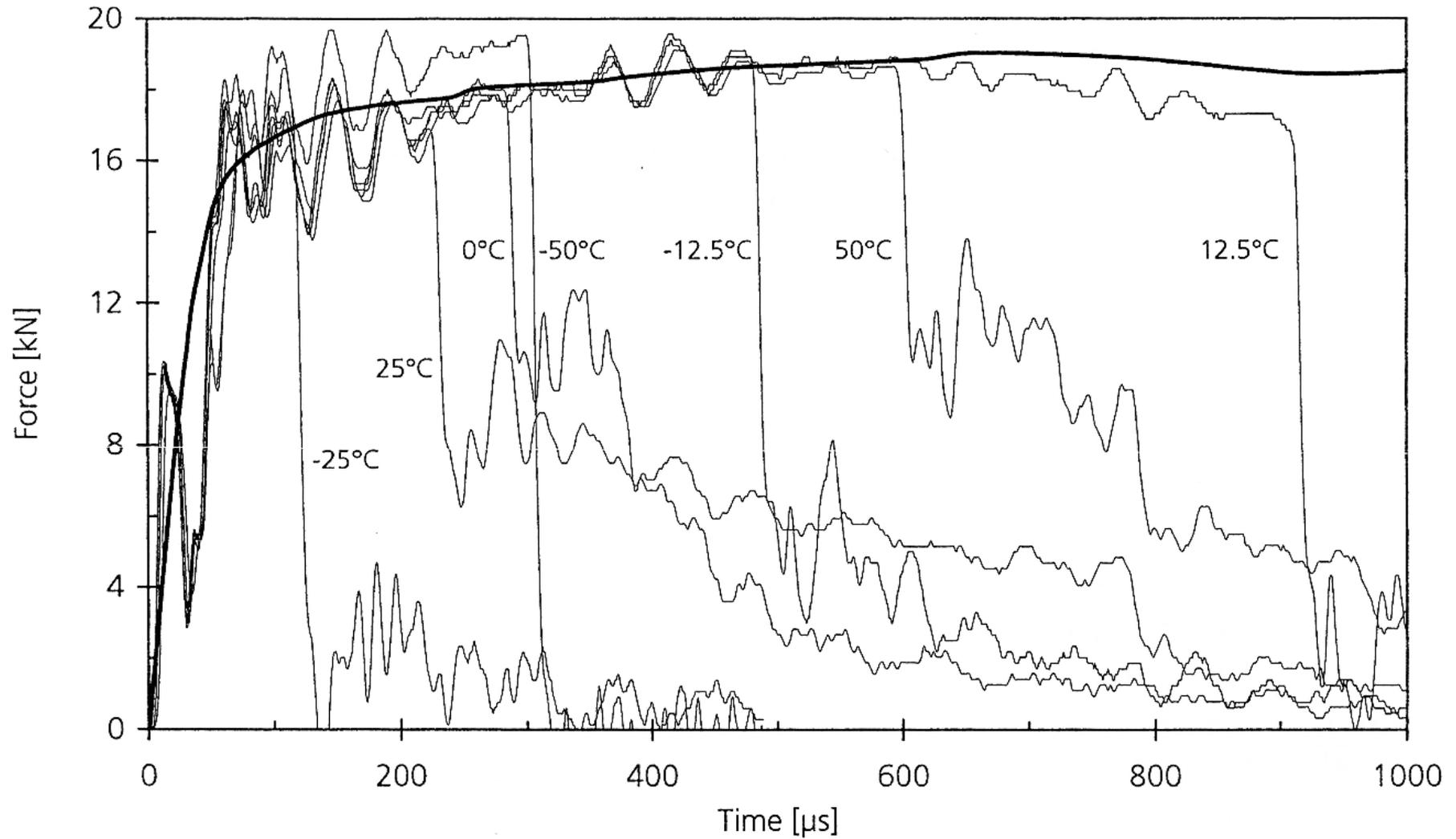
Impact test instrumented

The same KV

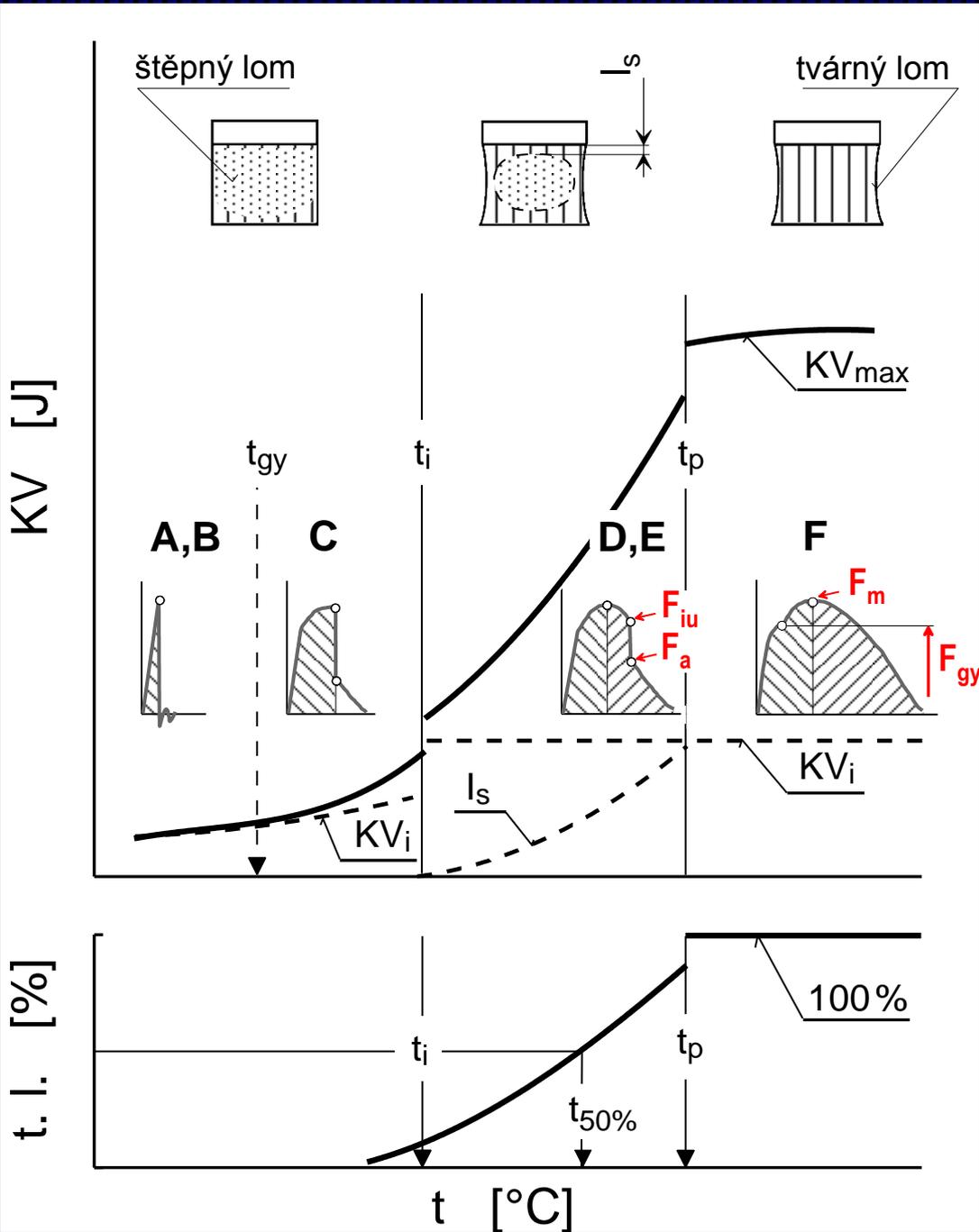
- Different fracture forces
- Different energy portions for initiation and for propagation



Impact test instrumented



Impact test instrumented



Comparative tests

Impact tests



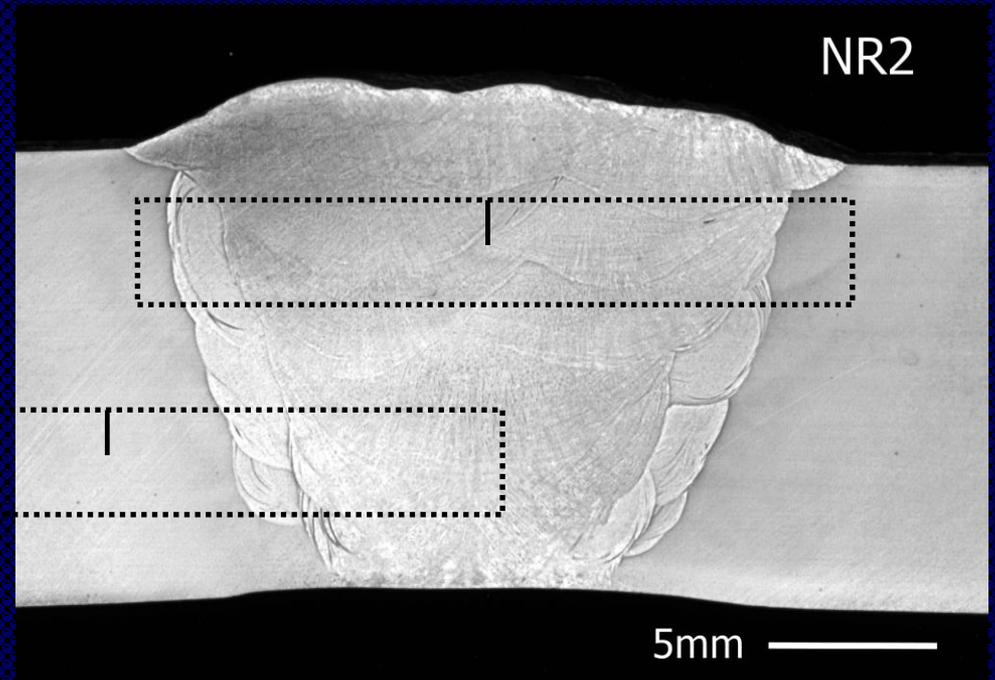
Value of KV is not possible to use directly for material selection and/or for component design calculation

All standards are based on practical experiences from long term use of materials

Newly formulated standards are based on correlation between transition temperature T_{27J} and value of K_{IC}

Impact tests

Comparative tests



Fracture diagram of Pellini

Specific tests - Robertson

Test machine 80 GN (8 000 tun)

Test samples 0,25 x 1,2 m

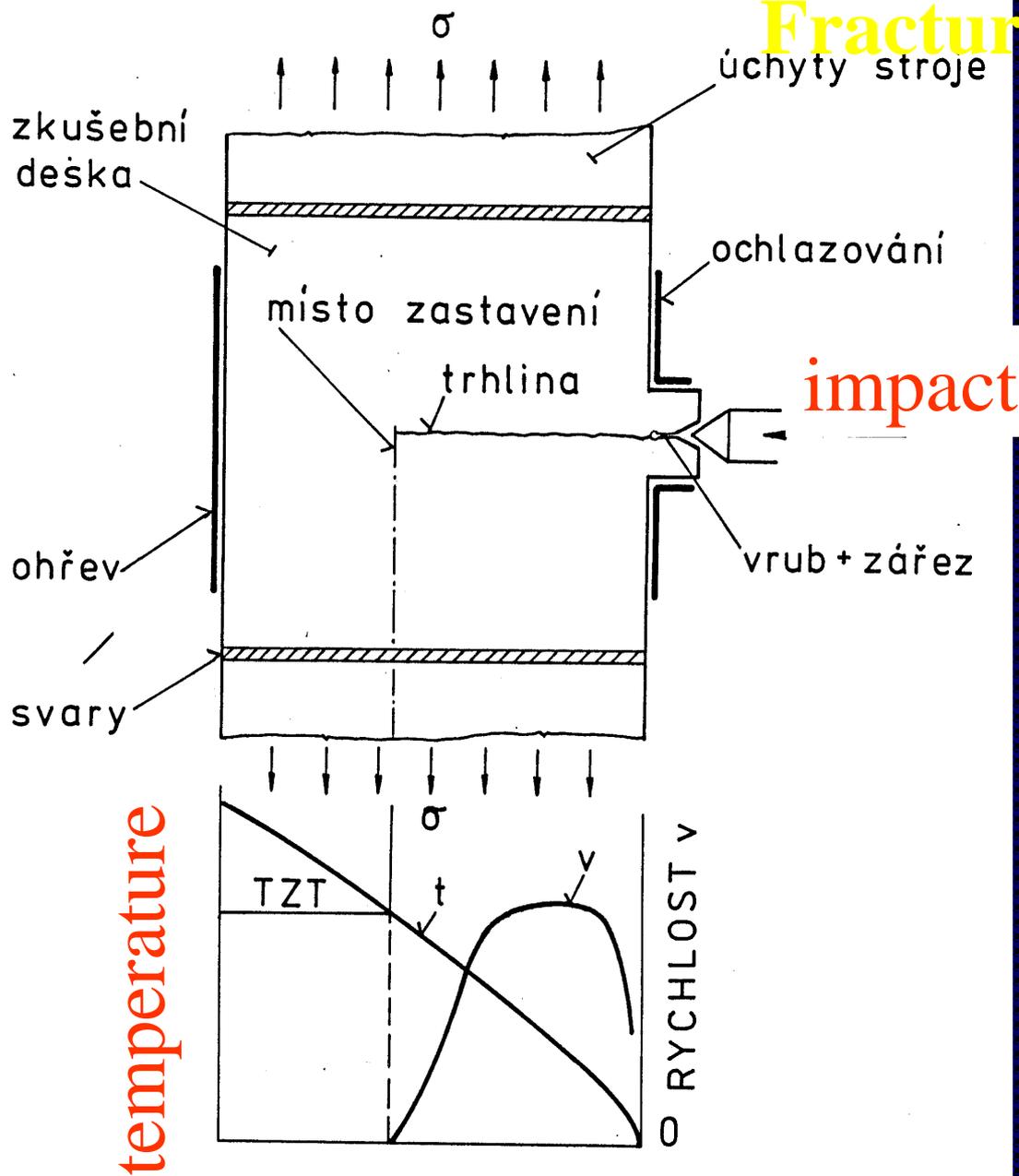
Aim of the test – to be as close as possible to real components conditions and to determine

- a) Temperature of crack arrest / test with temperature gradient
- b) Temperature of crack non propagation / test at constant temperature

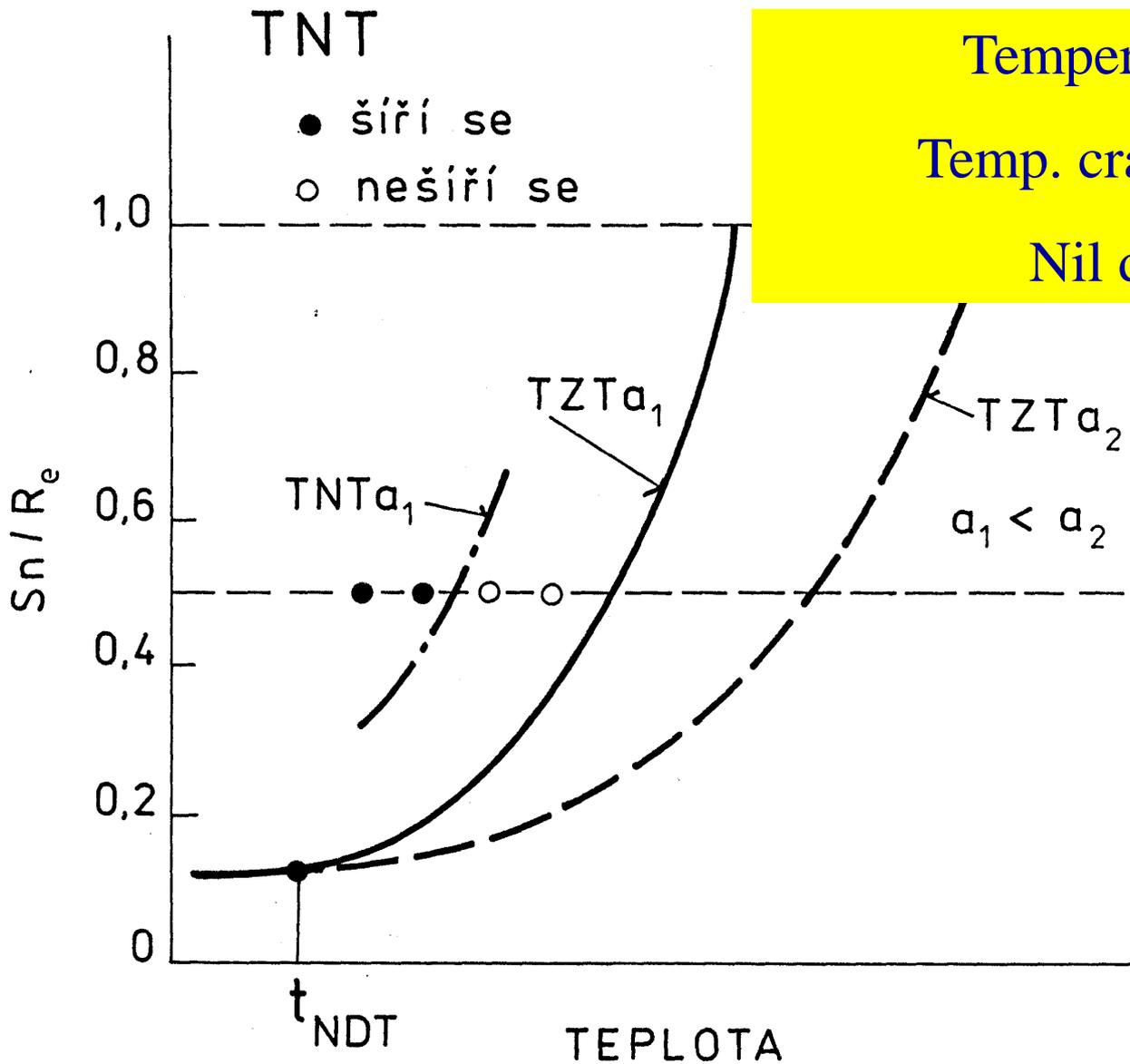
8000 t



Fracture diagram of Pellini



Fracture diagram of Pellini

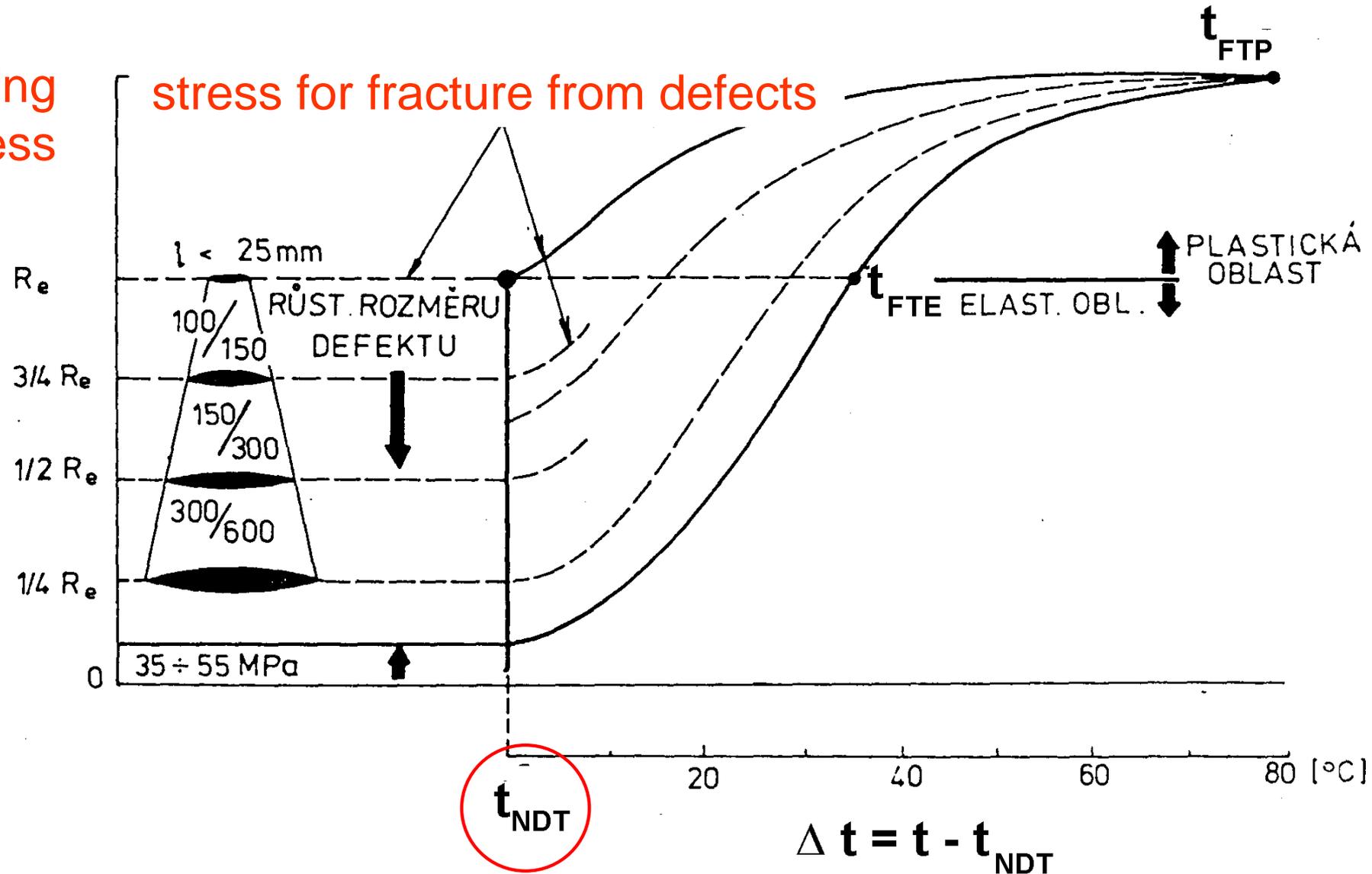


Temperature of crack arrest
Temp. crack non-propagation
Nil ductility temperature

35 – 55 MPa

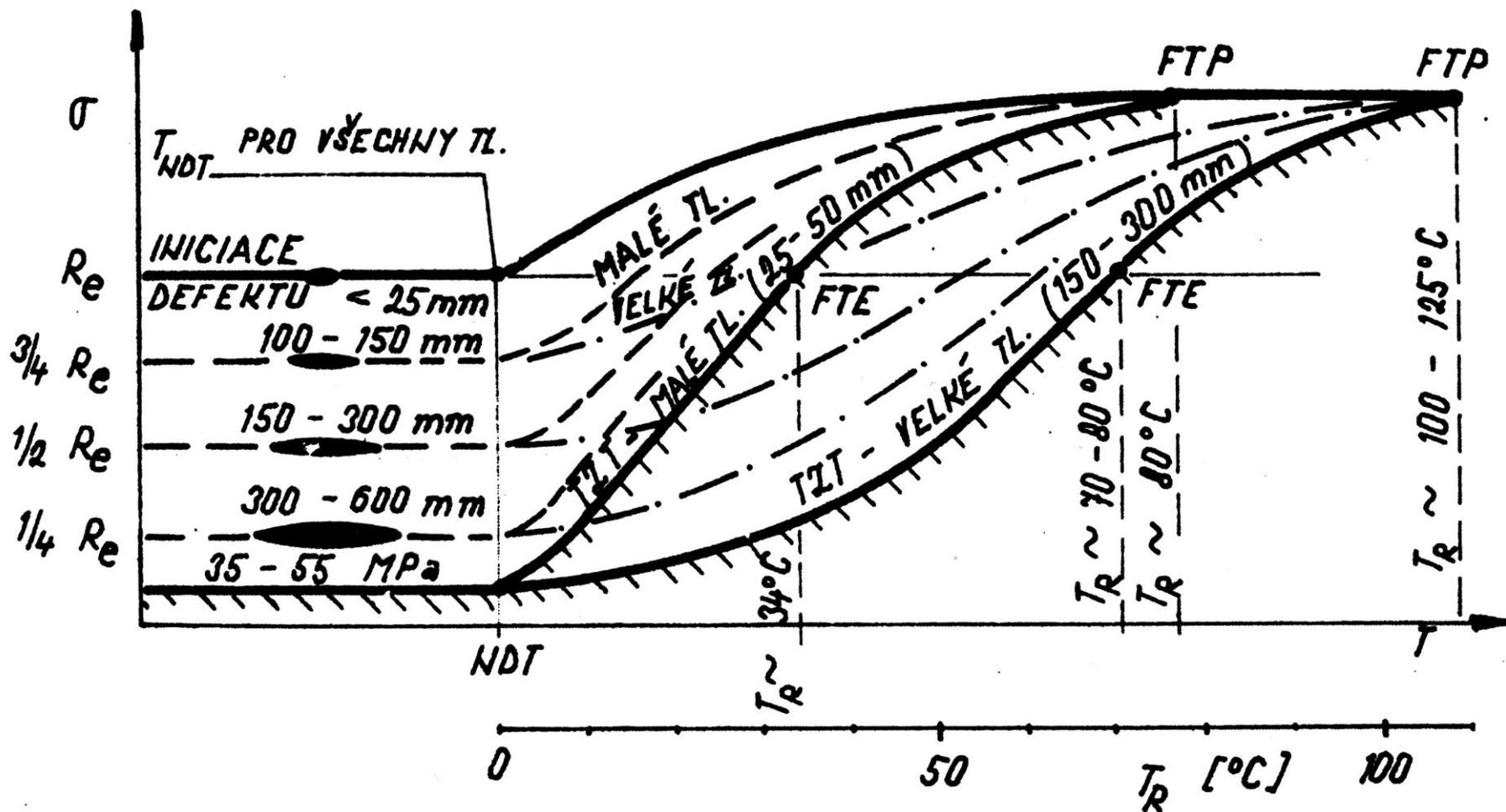
Fracture diagram of Pellini fracture analysis diagram

acting
stress



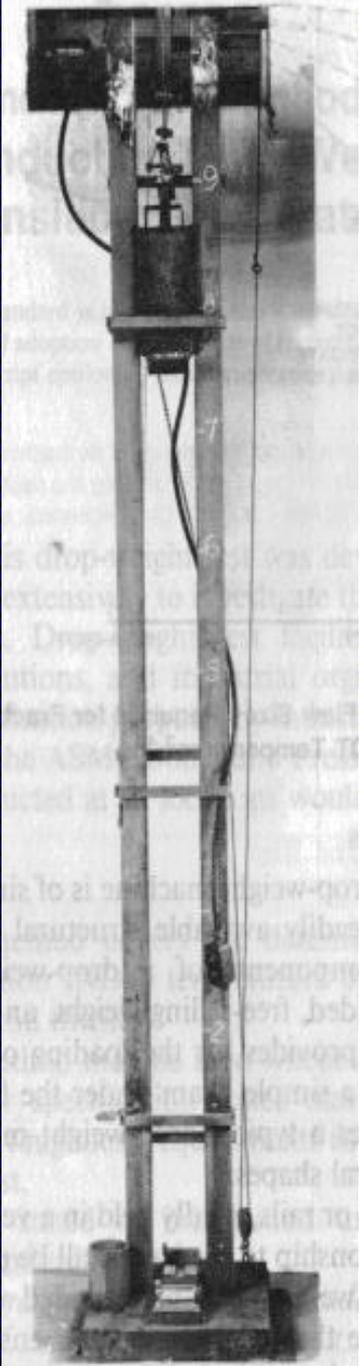
lomový diagram Pellini - Puzak 1960

(diagram FAD - Fracture Analysis Diagram)

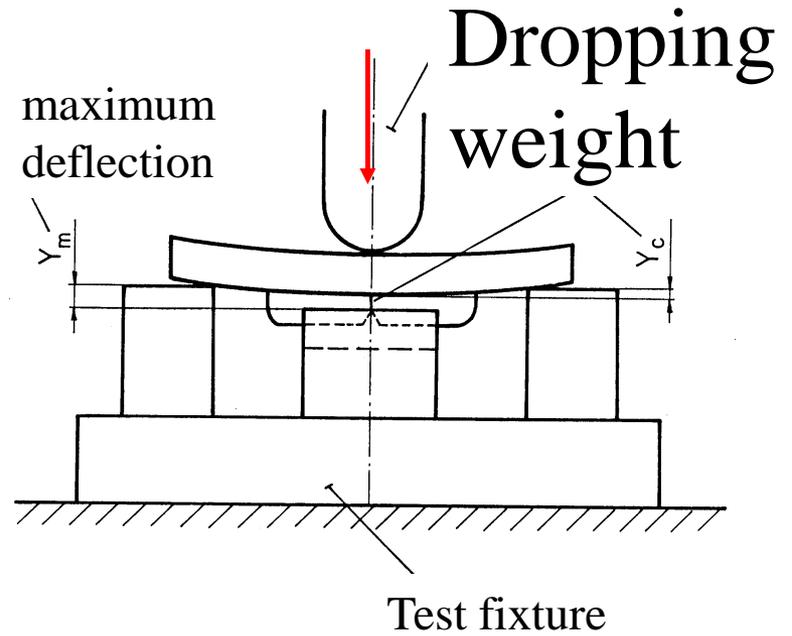
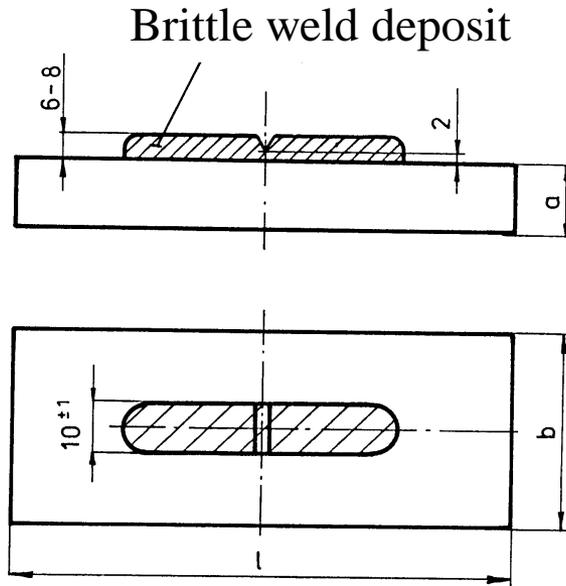


Drop weight test

t_{NDT} – nil ductility temperature

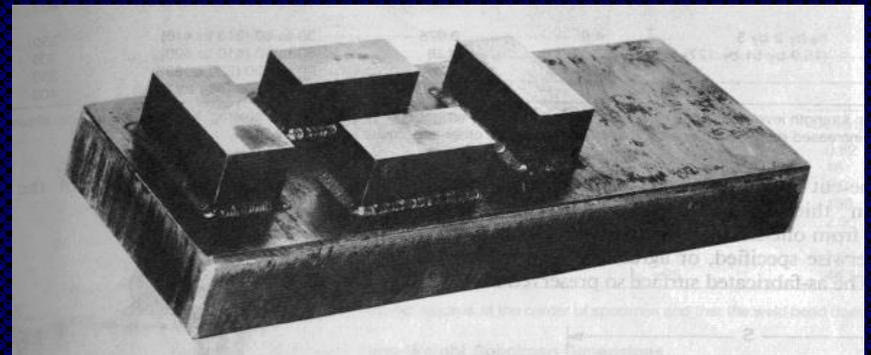


Drop weight test



OZNAČENÍ	a	b	l
16	16	50	130
19	19	50	130
25	25	90	360

Test specimens



Drop weight test

Aim of the test – determination of t_{NDT}

temperature limit above which no unstable fracture occurs from the notch at dynamic loading at stress corresponding to yield stress

t_{NDT} – highest temperature at which test specimens is broken (determination with accuracy $\pm 5^{\circ}\text{C}$)

operation temperature determination

$$t_{\text{appl}} = t_{\text{NDT}} + \Delta t \quad (\Delta t \cong 17^{\circ}\text{C})$$

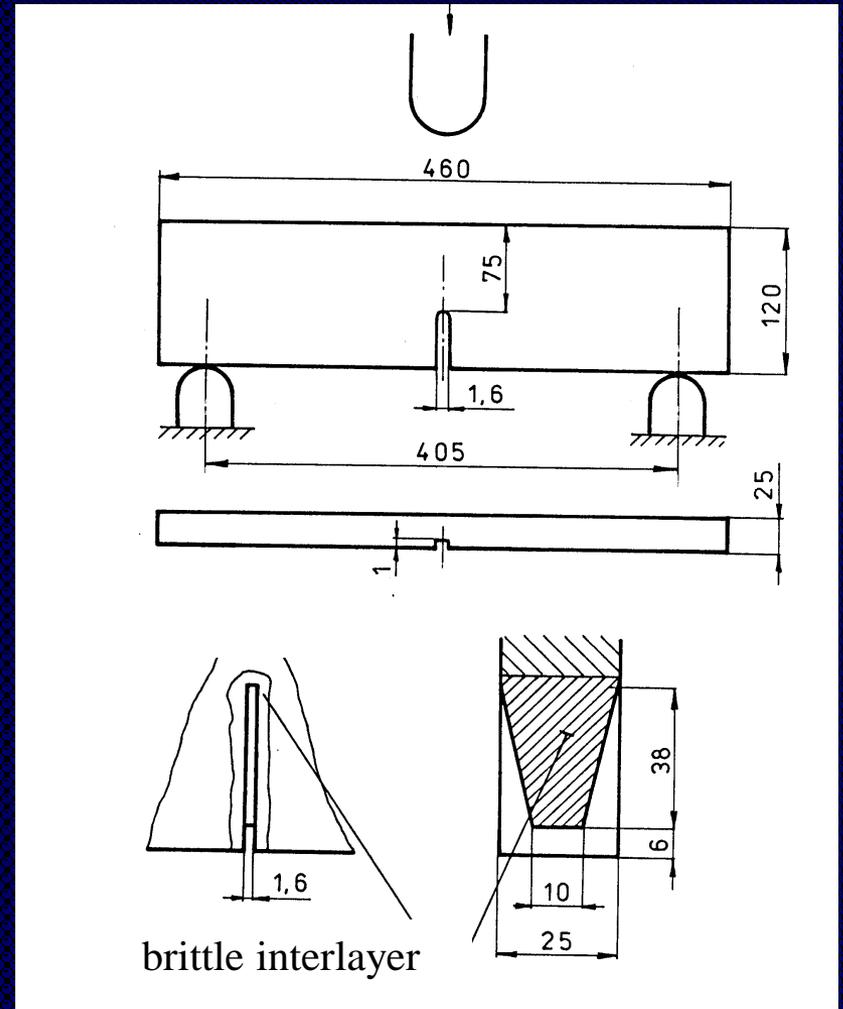
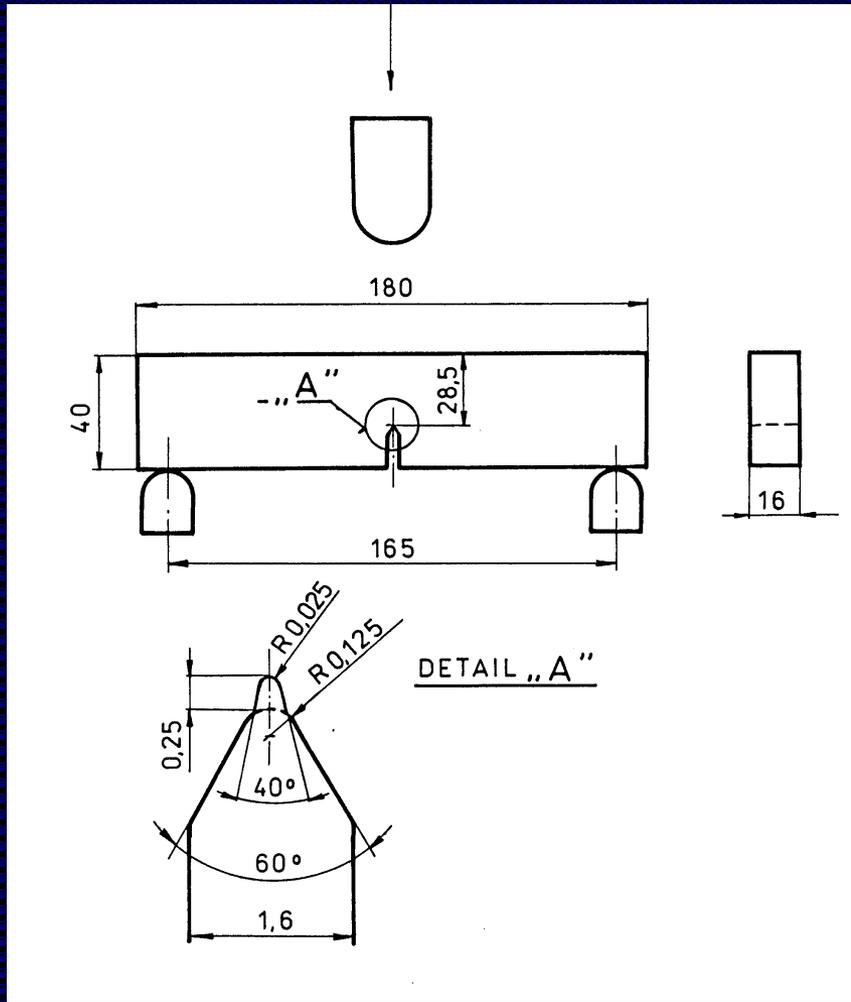
(Dynamically loaded weld structures, rotors of steam generators)

dynamic tear (DT) test of large samples

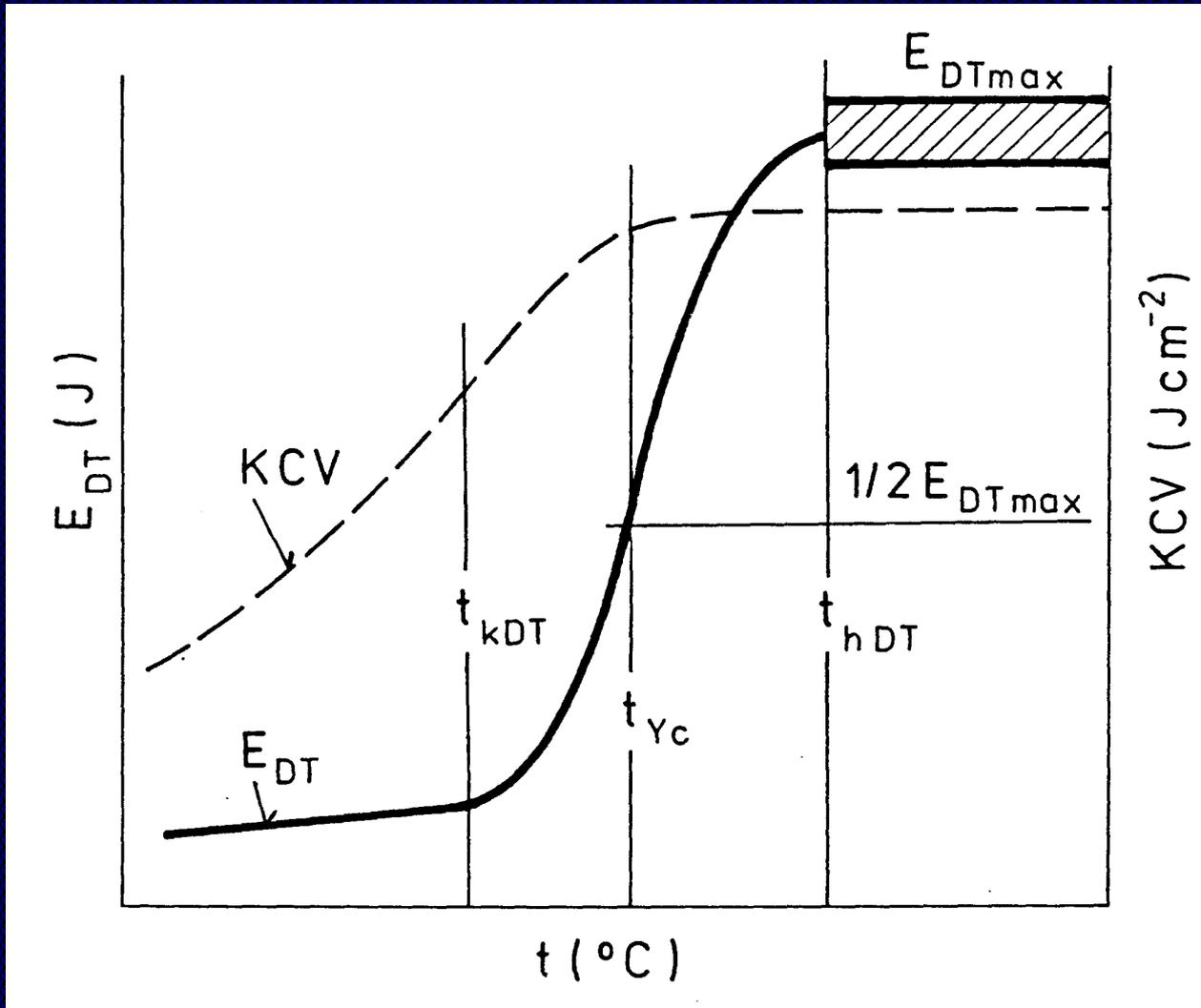
Test machine: impact pendulum 10 kJ

Measured parameter: DT energy – work absorbed
for crack propagation

dynamic tear (DT) test of large samples



dynamic tear (DT) test of large samples



Drop weight tear test (DWTT) of full thickness specimens

Introduced by „American Gas Association“

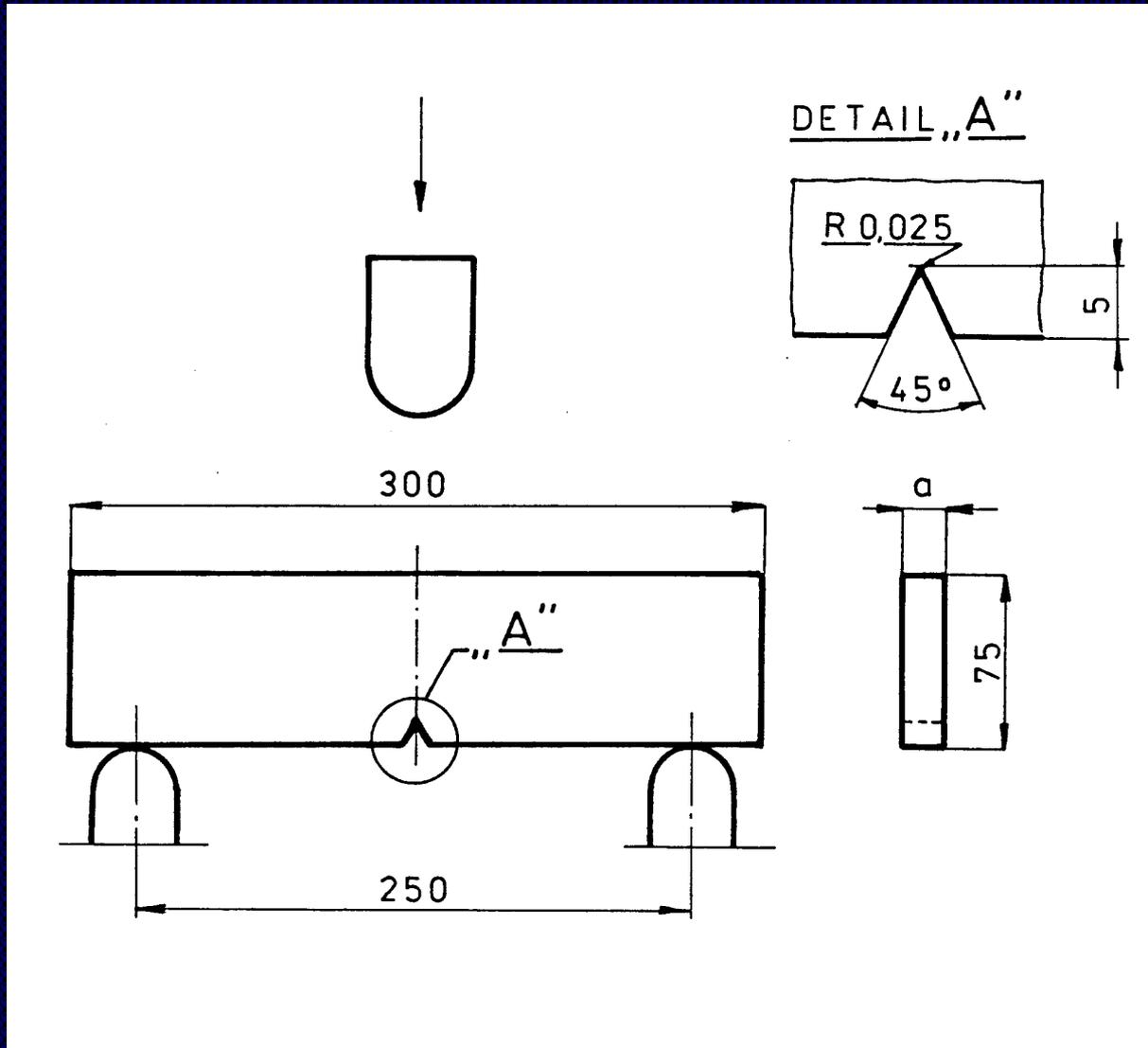
Aim: to determine transition temperature of steel sheets for production of pressure piping (pressurised vessels) containing gas

Test machine: impact pendulum or drop weight tester

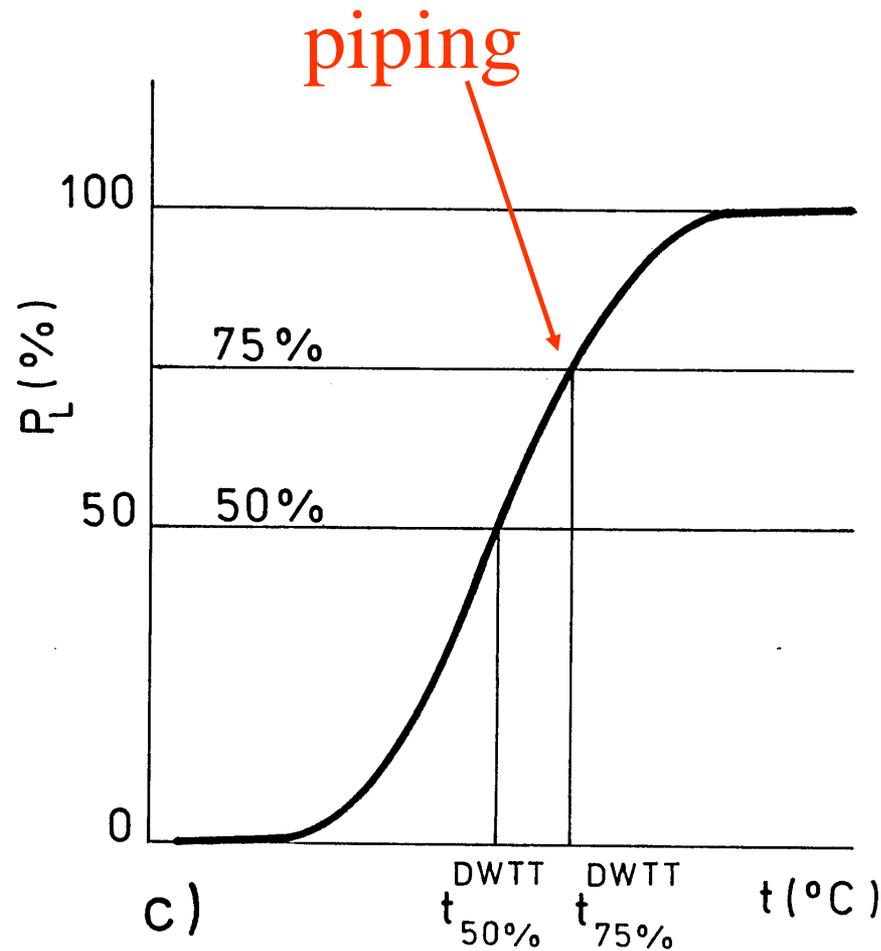
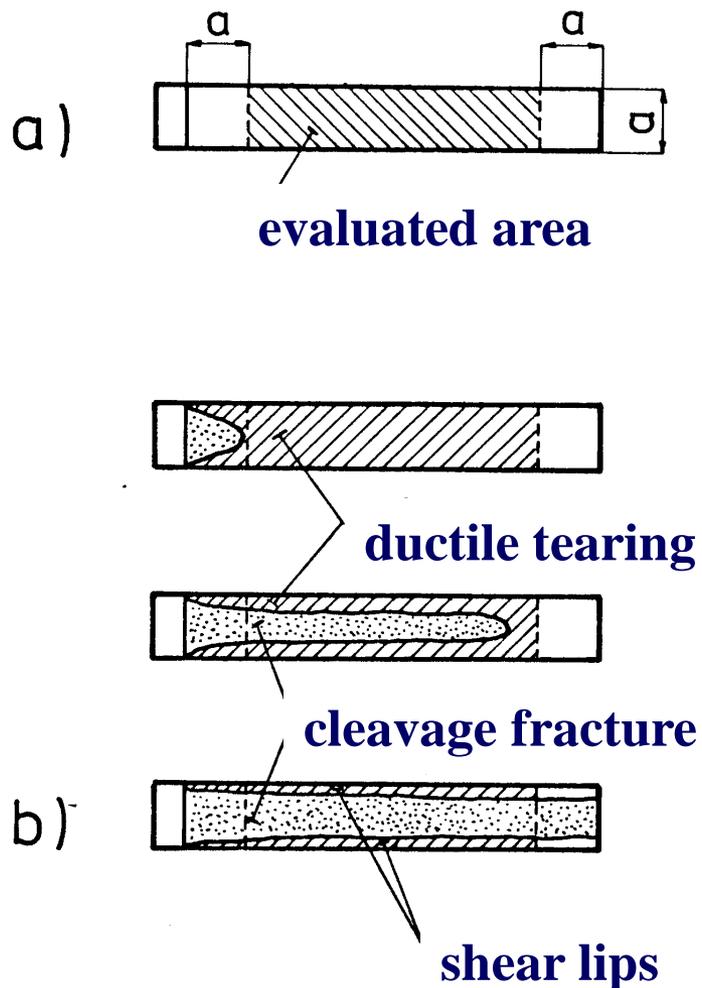
Specimen thickness corresponds to component thickness

Evaluated parameter: fracture surface morphology

Drop weight tear test (DWTT) of full thickness specimens



Drop weight tear test (DWTT) of full thickness specimens





Emprical tests

- ❖ Impact test
- *Comprative*  $t_{50\%}$ - FATT, t_{27J} , DBTT etc
- ❖ Instrumented impact
- *Specific* KV_i , KV_p , t_{GY} , etc.
- ❖ transition temperature concepts

Tests

- *Comparative*

- ❖ Robertson test

- t. arrest crack,

- t. non-propagating crack

- *Specific*



- ❖ Pellini diagram - t_{NDT} , t_{FTE}

- ❖ Drop weight test DWT - t_{NDT}

- ❖ Drop weight test of samples having initial thickness DWTT - t_{50}^{DWTT}