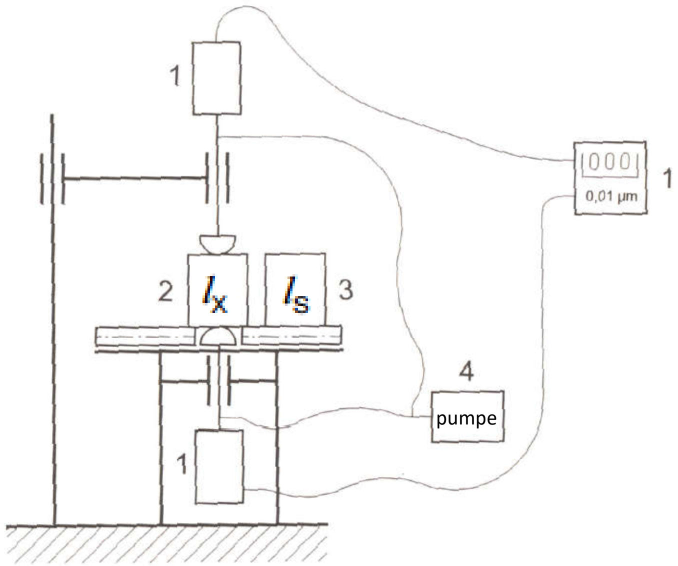
Kalibrering av passbiter ved komparering:

Toleranser	00	0	1	2
L = 50 mm	0,10	0,20	0,40	0,80
L = 100 mm	0,14	0,30	0,60	1,20



$$\Delta l_x = L\,\alpha_x\,(t_x - t_0)$$

$$\Delta l_s = L\,\alpha_s\,(t_s - t_0)$$

$$\Delta l_x = 0{,}1\,m \cdot 11{,}5\ \mu/\mathrm{K} \cdot 0{,}5\ \mathrm{K} = 0{,}58\ \mu\mathrm{m}$$

$$\Delta l_s = 0{,}1\,m \cdot 4{,}25\ \mu/\mathrm{K} \cdot 0{,}5\ \mathrm{K} = 0{,}21\ \mu\mathrm{m}$$

$$\Delta l = 0{,}37\ \mu m$$

Målefunksjonen: $l_x' = l_s' + \delta l$

$$l_x + L\alpha_x(t_x - t_0) = l_s + \delta l_D + \delta l + \delta l_C - \delta l_V + L\alpha_s(t_s - t_0)$$

L	-	nominal length of the gauge blocks considered;
$\bar{\alpha} = (\alpha_X + \alpha_S)/2$	-	average of the thermal expansion coefficients of the unknown and reference gauge blocks;
$\delta\alpha = (\alpha_X - \alpha_S)$	-	difference in the thermal expansion coefficients between the unknown and the reference gauge blocks;
$\Delta\bar{t} = (t_X + t_S)/2 - t_0$	-	deviation of the average temperature of the unknown and the reference gauge blocks from the reference temperature;
$\delta t = (t_X - t_S)$	-	temperature difference between the unknown and reference gauge blocks;

$$l_x = l_s + \delta l_D + \delta l + \delta l_C - \delta l_V - L\,\bar{\alpha}\,\delta t - L\,\delta\alpha\,\Delta\bar{t}$$

Se også målefunksjonen i EA-4/02 S4
http://www.european-accreditation.org/publication/ea-4-02-m-rev01-september-2013

Usikkerhet pga temperatur:

Toleranser	00	0	1	2
L = 50 mm	0,10	0,20	0,40	0,80
L = 100 mm	0,14	0,30	0,60	1,20

$$l_x = l_s + \delta l_D + \delta l + \delta l_C - \delta l_V - L\,\bar{\alpha}\,\delta t - L\,\delta\alpha\,\Delta\bar{t}$$

$u_1(L\,\bar{\alpha}\,\delta t)$

$E(\delta t) = 0$

$$u(\delta t) = \frac{50\ mK}{\sqrt{3}} = 29\ mK$$

$u_2(L\,\delta\alpha\,\Delta\bar{t})$

$E(\Delta\bar{t}) = 0$

$$u(\Delta\bar{t}) = \frac{0{,}5\ K}{\sqrt{3}} = 0{,}29\ K$$

$\alpha_x = \alpha_s = \alpha_{stål}$

$u_1 = L\,u(\bar{\alpha}\,\delta t) = L\,\bar{\alpha}\,u(\delta t) = 0{,}033\ \mu m$

$E(\delta\alpha) = 0$

$u_2 = L\,u(\delta\alpha\,\Delta\bar{t}) = 0{,}024\ \mu m$

$\alpha_x \neq \alpha_s$:

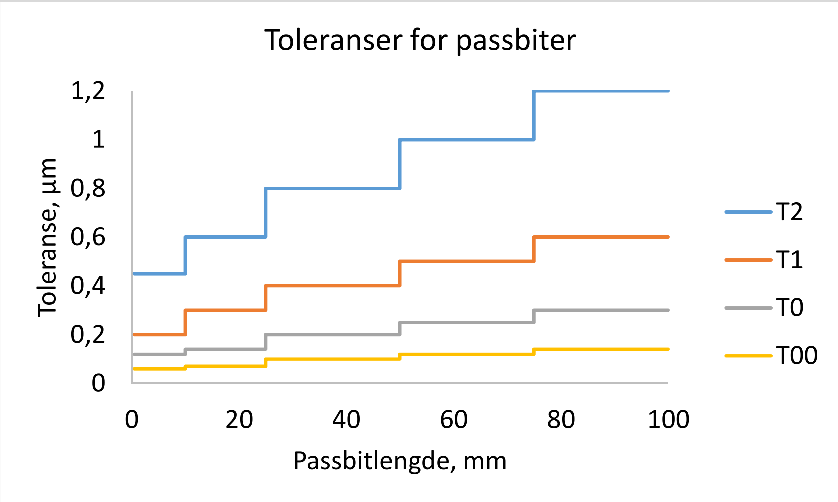
$u_1 = L\,u(\bar{\alpha}\,\delta t) = L\,\bar{\alpha}\,u(\delta t) = 0{,}023\ \mu m$

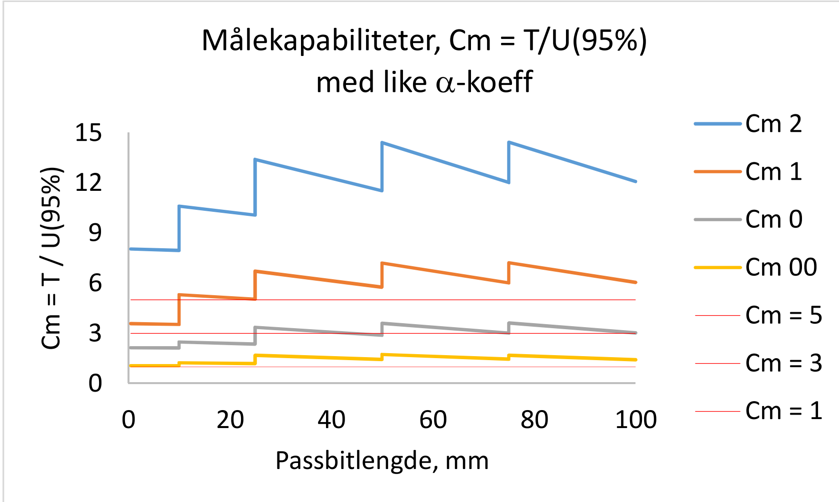
$E(\delta\alpha) \neq 0$

$u_2 = u(L\,\delta\alpha\,\Delta\bar{t}) = L\,\delta\alpha\,u(\Delta\bar{t}) = 0{,}21\ \mu m$

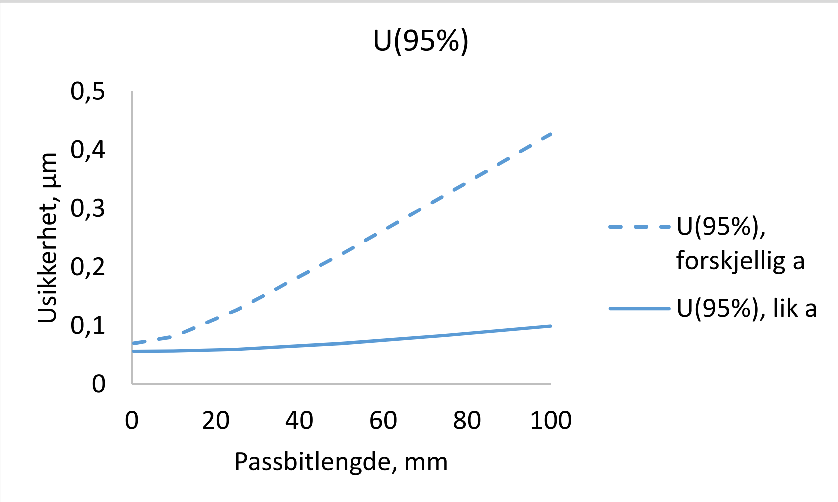
Å bruke forskjellig materiale i bitene i komparatoren medfører stor usikkerhet i lengdemålingen pga denne usikkerhetskomponenten!

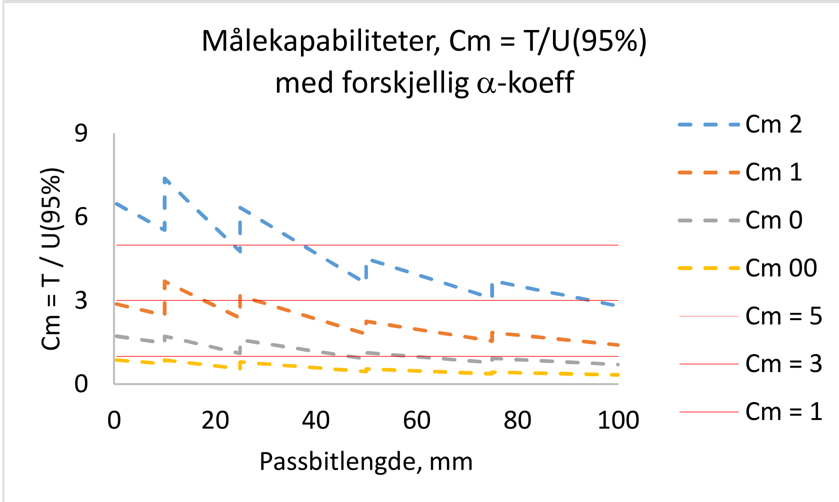
Målekapabilitet for passbiter med like α eller forskjellig α :



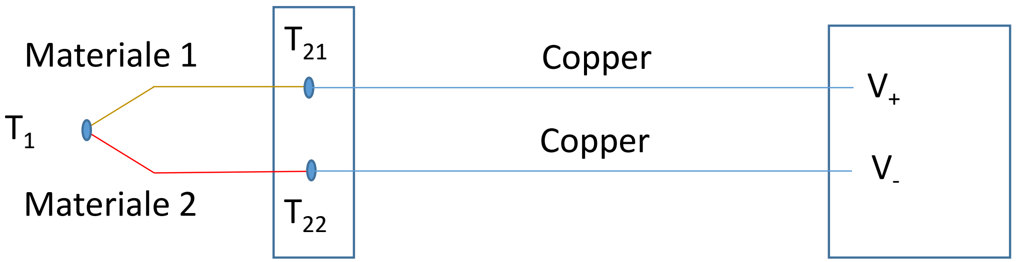


$$C_m = \frac{Toleranse}{U(95\%)}$$





Termoelement, klassisk konfigurasjon

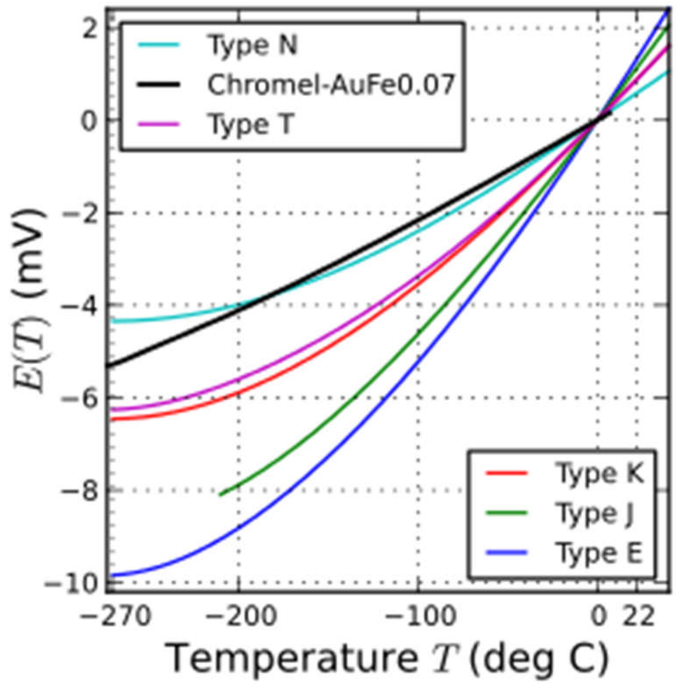


$T_1 \neq T_2$ $\quad$ $T_{21} = T_{22}$ $\quad$ $T_+ = T_-$

$V_{21} \neq V_{22}$ $\quad$ $V_+ \neq V_-$

$$\Delta V = V_+ - V_-$$
$$= (V_+ - V_{21}) + (V_{21} - V_1) + (V_1 - V_{22}) + (V_{22} - V_-)$$
$$= S_{Cu}(T_+ - T_{21}) + S_{M1}(T_{21} - T_1) + S_{M2}(T_1 - T_{22}) + S_{Cu}(T_{22} - T_-)$$
$$= S_{M1}(T_2 - T_1) - S_{M2}(T_2 - T_1)$$
$$= E_{Type\ T}(T_2 - T_1)$$

"The underlying solid-state physics is rather complicated but the phenomenon is well understood. The magnitude and sign of the Seebeck coefficient are related to an asymmetry of the electron distribution around the Fermi level. For example, the theory explains not only the different signs for metals but also why the Seebeck coefficient is much larger in semiconductors than in metals."

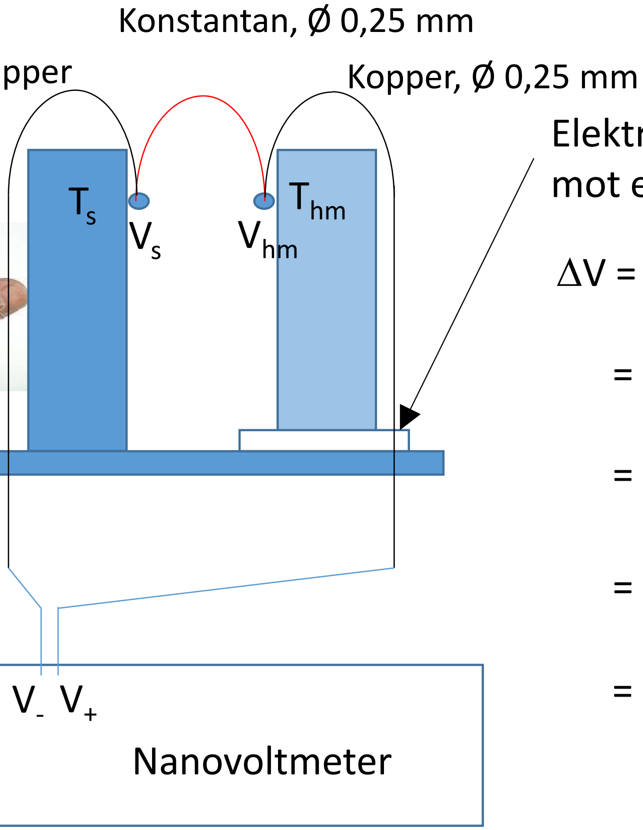


	Seebeck coefficient, µV/K
Constantan:	-35 µV/K
Copper:	+6,5 µV/K

I beregningene forutsettes homogent materiale (samme S) langs hele lederen, og vi får:

$$\Delta V = \int_{T_1}^{T_2} S_M \, dT = S_M \,(T_2 - T_1)$$

Måling av temperaturforskjell, $\delta T = T_s - T_{hm}$, med termoelement type T



Tilkoplingsledninger, også koppertråd.

Elektrisk (og termisk) isolasjon mot et elektrisk ledende bord

$$\Delta V = V_+ - V_-$$

$$= (V_+ - V_{hm}) + (V_{hm} - V_s) + (V_s - V_-)$$

$$= S_{Cu}(\cancel{T_+} - T_{hm}) + S_C(T_{hm} - T_s) + S_{Cu}(T_s - \cancel{T_-})$$

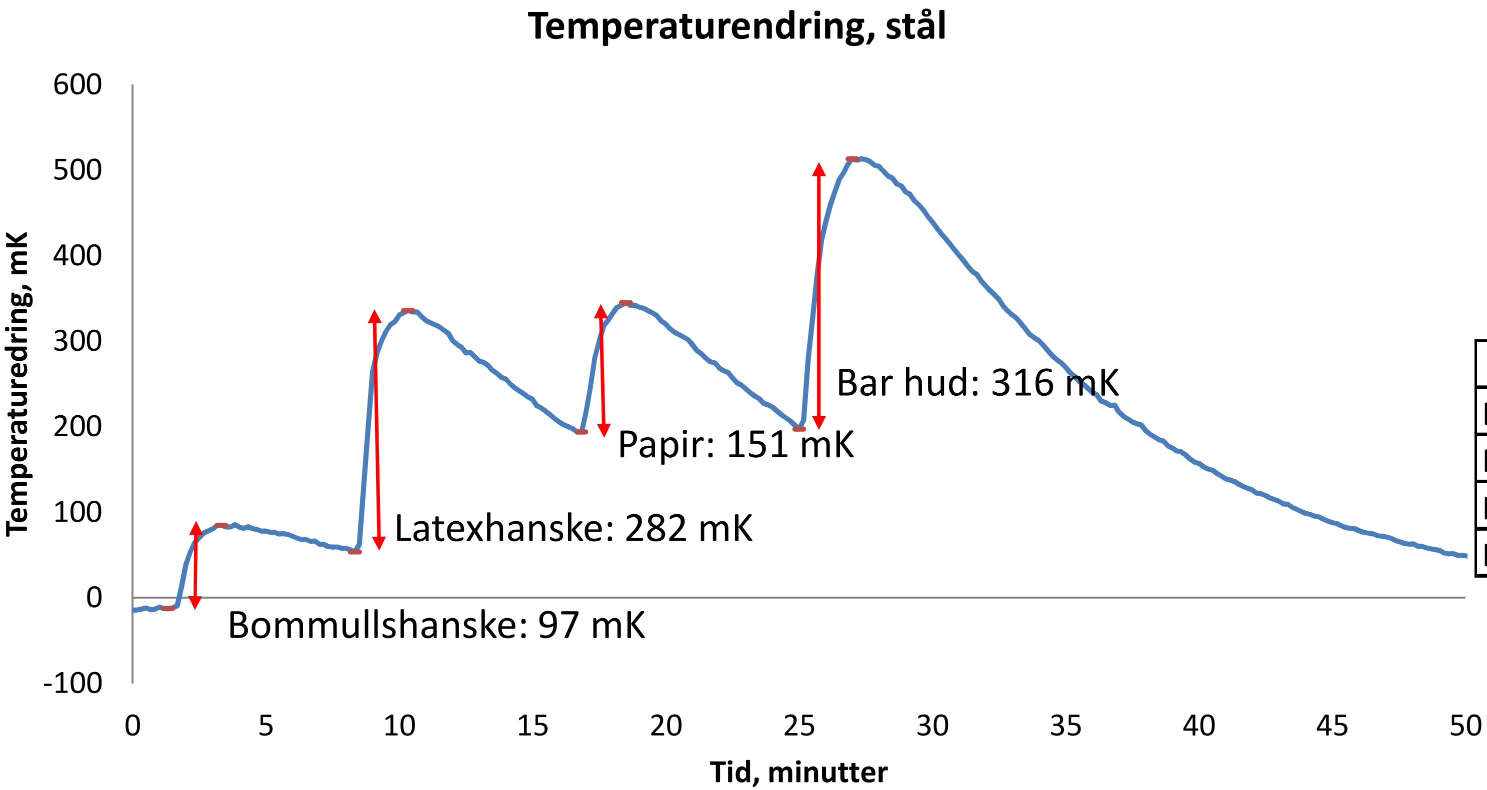
$$= S_{Cu}(T_s - T_{hm}) - S_C(T_s - T_{hm})$$

$$= E_{Type\ T}(T_s - T_{hm})$$

Sensitivitet nær 20 °C,
type T-element: 40 µV/K
Det vil si: 25 mK/µV

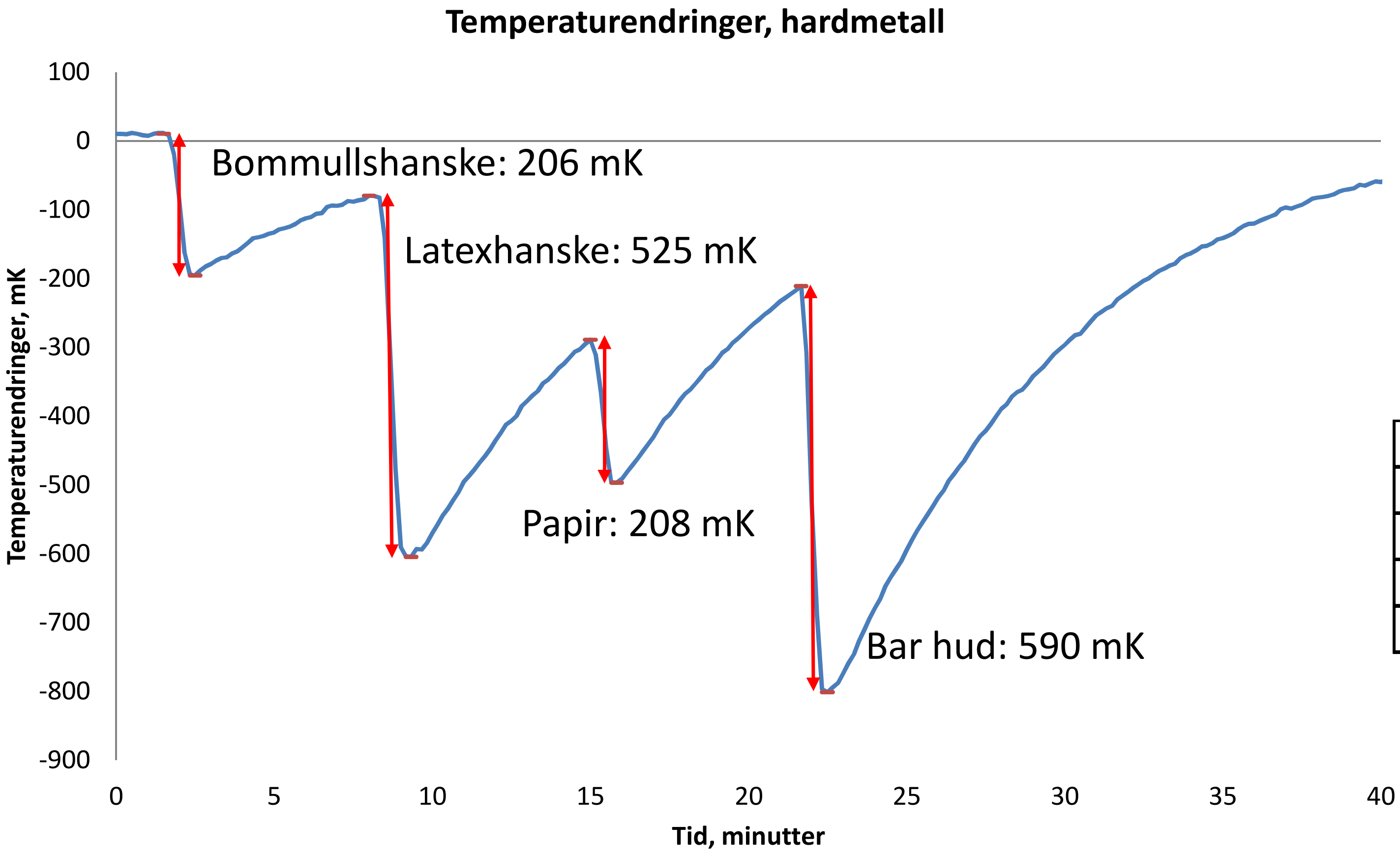
Takk til Max Sievert ved Lars Gulliksen og Finn Enger!

Typisk temperaturendring for stål, 30 s oppvarming



	Gj.snitt	stdav
Bomullshanske	0,61	0,29
Latexhanske	1,27	0,45
Papir	0,57	0,22
Bar hud	1,00	

Typisk temperaturendring for hardmetall:



	Gj.snitt	stdav
Bomullshanske	0,37	0,17
Latexhanske	0,93	0,30
Papir	0,44	0,07
Bar hud	1,00	

Bestemmer tidskonstanten, τ, for stål:

$$\Delta T = \Delta T_{Offset} + (T_{Start} - \Delta T_{Offset}) \cdot e^{-t/\tau}$$

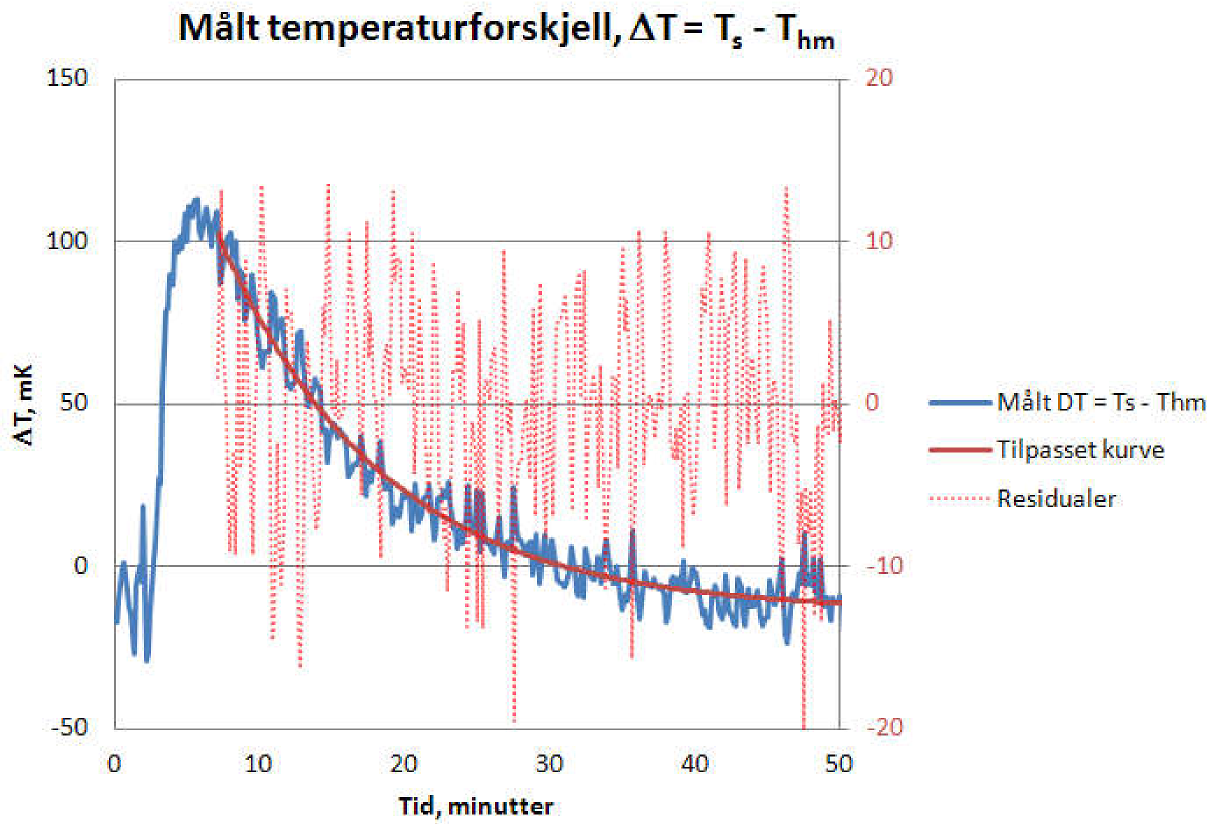
$$\Delta T_{Start} = 102\ mK$$

$$\Delta T_{Offset} = -14\ mK$$

$$\tau = 11{,}3\ min$$

	T_{Start}	ΔT_{Offset}	τ
1	-150	-16	11,0
2	-102	-14	11,3
3	-175	-10	10,5

Gjennomsnitt, τ = 10,91 min
Stdav til gj.snitt, s/√3 = 0,22 min



Bestemmer tidskonstanten, τ, for hardmetall:

$$\Delta T = \Delta T_{Offset} + (T_{Start} - \Delta T_{Offset}) \cdot e^{-t/\tau}$$

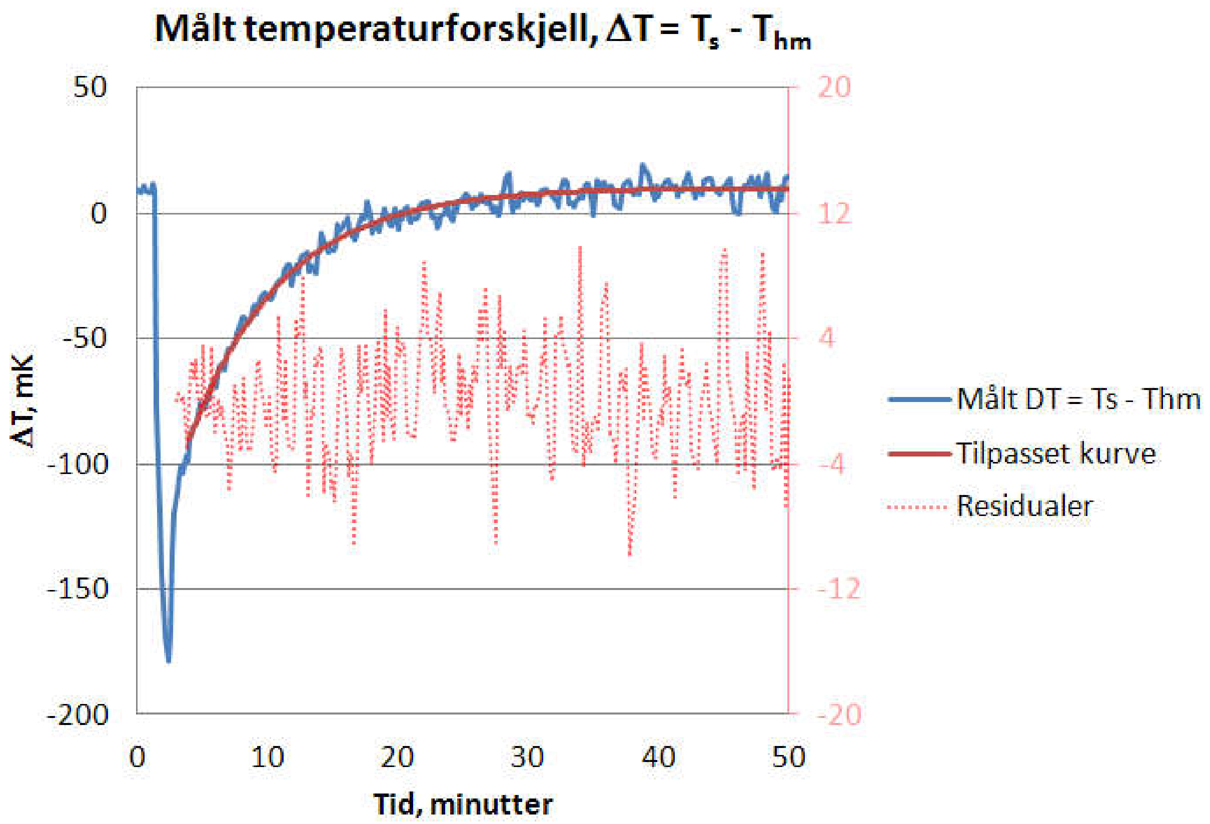
$$\Delta T_{Start} = -90\ mK$$

$$\Delta T_{Offset} = 10\ mK$$

$$\tau = 7{,}2\ min$$

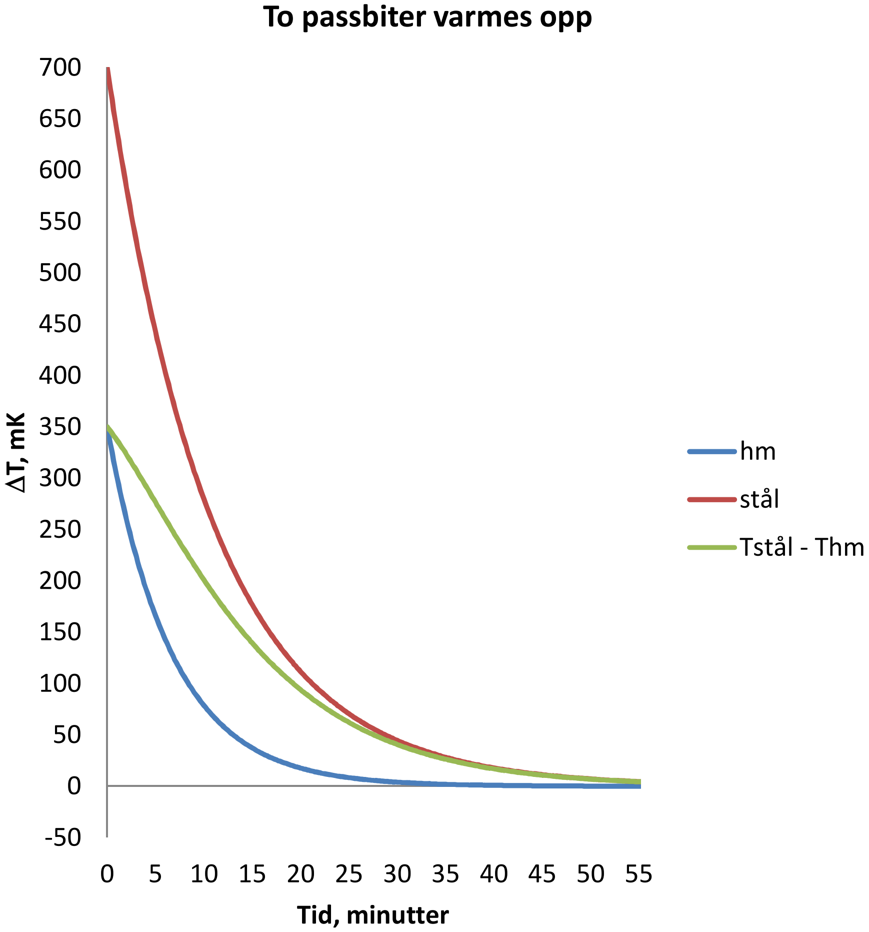
	T_{Start}	ΔT_{Offset}	τ
1	100	3	7,3
2	90	10	7,2
3	200	13	5,6

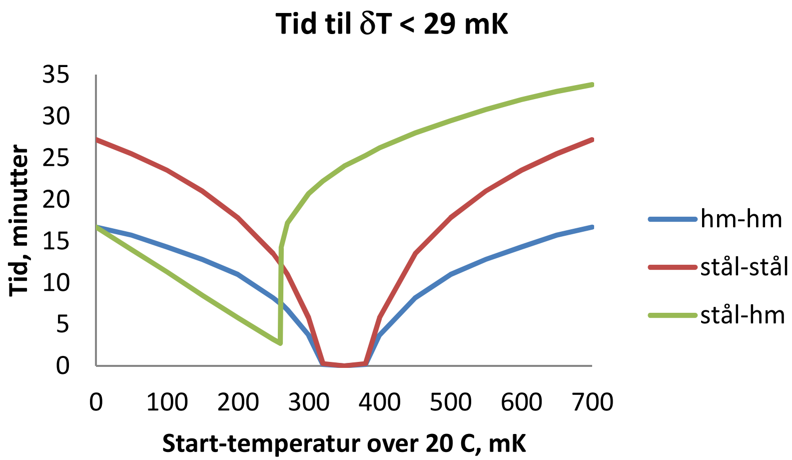
Gjennomsnitt, τ = 6,70 min
Stdav til gj.snitt, s/√3 = 0,55 min



Hvor lang tid tar temperaturstabiliseringen, δt nær 0?

δt kan bli liten nokså fort,
Men vi har korreksjon og usikkerhet i Δt også!
Den blir stor når $\alpha_1 \neq \alpha_2$





<u>Lord Kelvin (1824 – 1907):</u>
«I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind.»