This Online Resource contains electronic supplementary material (ESM) accompanying the following article submitted to the

International Journal of Biometeorology – Special Issue (UTCI)

Deriving the Operational Procedure for the Universal Thermal Climate Index UTCI

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ESM 1 Responses to UTCI for the following single variables calculated from the output of the UTCI simulation model

ESM 1a Responses averaged over values after 30, 60, 90 and 120 min vs. UTCI

ESM 1b Responses averaged over values after 30, 60, 90 and 120 min vs. UTCI for the Reference Conditions only

ESM 1c Early (30 min) and late (120 min) responses vs. UTCI for the Reference Conditions

ESM 2 Criteria used for categorizing values of UTCI in terms of thermal stress

ESM 3 Coefficients of a 6th order polynomial regression function approximating the **Offset** (= UTCI – Ta) in °C from input values of air temperature (**Ta**) in °C, of wind speed 10 m above ground level (**va**) in m/s, of water vapour pressure (**pa**) in kPa and of the difference between mean radiant temperature and air temperature (**tm**) in °C. The equation is valid for the input parameters ranging as follows:
-50 °C ≤ Ta ≤ +50 °C,
va ≤ 30.3 m/s
-30 °C ≤ tm ≤ +70 °C
pa ≤ 5 kPa (relative humidity ≤ 100%)

ESM 4 The TAB-delimited file "ESM_4_Table_Offset.Dat" tabulates values of the Offset (= UTCI - Ta) in °C for different input values of:

Ta:	air temperature in°C (range: -50 °C to +50 °C)
Tr-Ta:	difference between mean radiant temperature (Tr) and air temperature in °C (-30 °C to +70 °C)
va:	wind speed in m/s measured 10 m above ground level (0.5 m/s to 30.3 m/s)
rH:	relative humidity in % (5% to 100%)
pa:	water vapour pressure in kPa (0 kPa to 5 kPa)

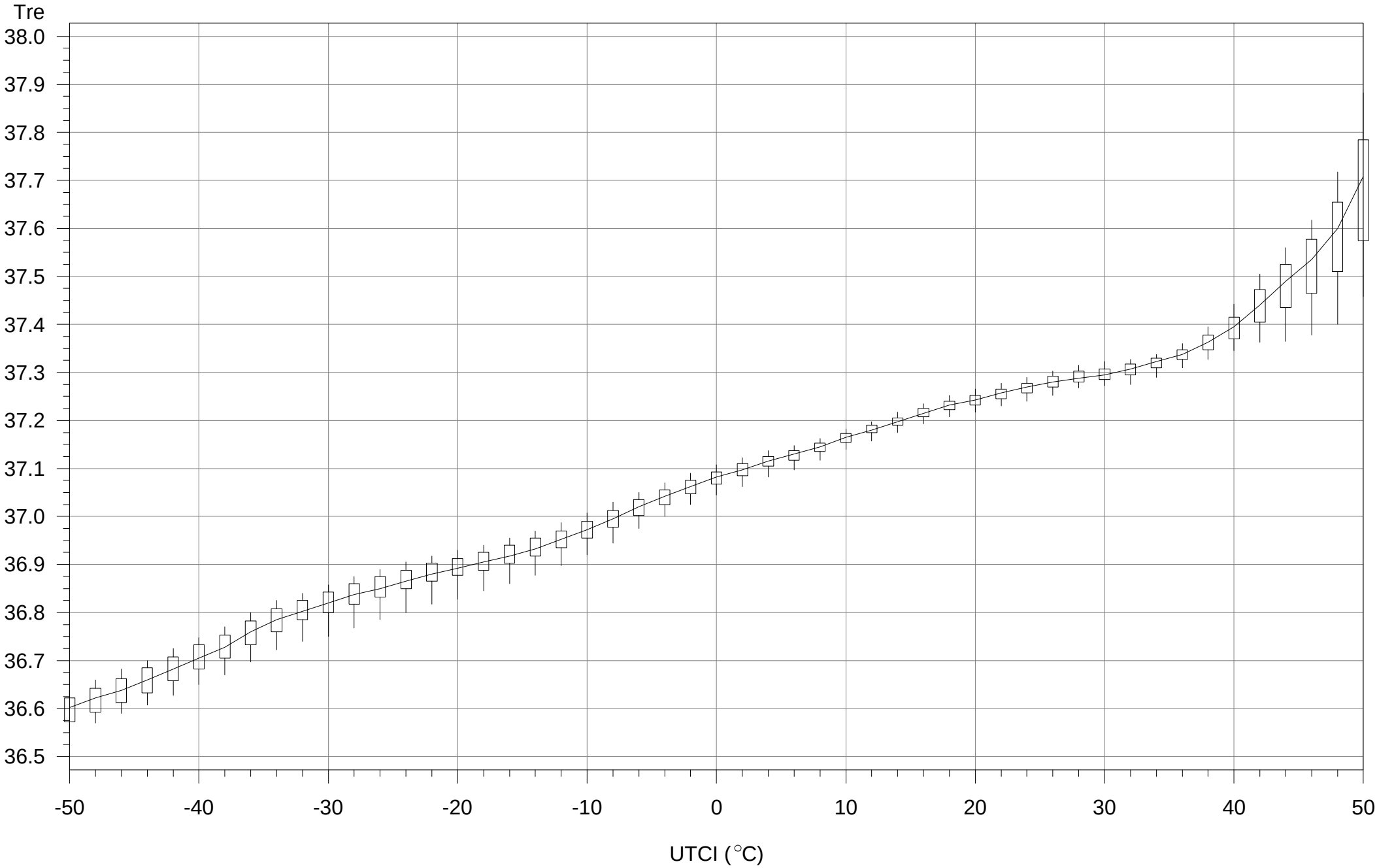
ESM 1: Responses to UTCI for the following single variables calculated from the output of the UTCI simulation model

	Variable	Abbreviation	Unit
1.	rectal temperature	Tre	°C
2.	mean skin temperature	Tskm	°C
3.	face skin temperature	Tskfc	°C
4.	hand skin temperature	Tskhn	°C
5.	total net heat loss	Qsk	W
6.	evaporative (latent) heat loss	Esk	W
7.	sweat production	SR	g/h
8.	metabolic heat production	Metab	W
9.	heat generated by shivering	Shiv	W
10.	skin wettedness	wettA	% of body area
11.	skin blood flow	VblSk	% of basal value
12.	cardiac output	sVbl	% of basal value
13.	core to skin temperature gradient (Tre-Tskm)	K	°C
14.	step change in Tskm after entering climate	Tsk_dot	K/min
15.	Dynamic Thermal Sensation (-3 … +3)	DTS	nd
16.	time gradient in rectal temperature	D_Tre	K/h
17.	time gradient in mean skin temperature	D_Tskm	K/h

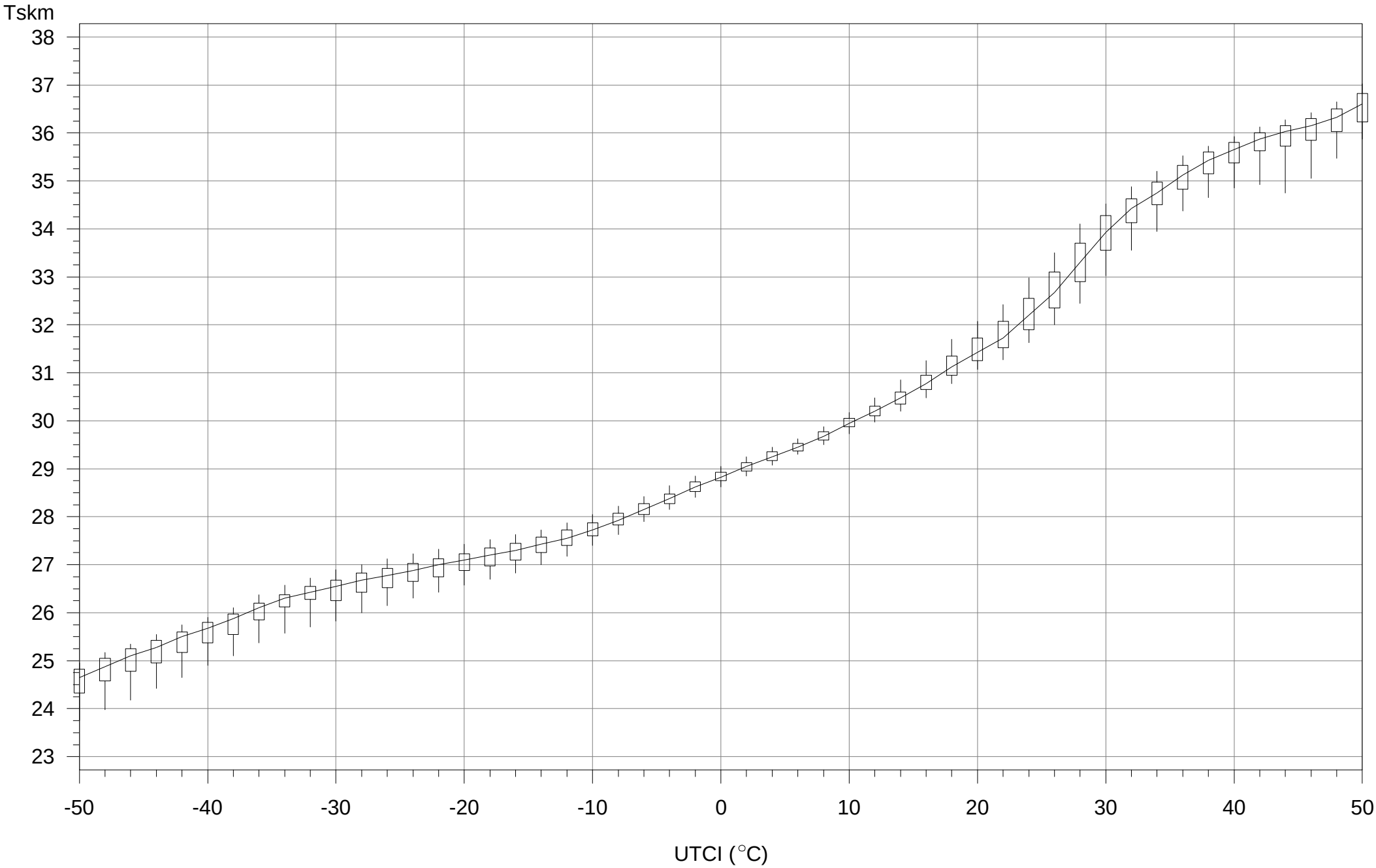
ESM 1a: Responses averaged over values after 30, 60, 90 and 120 min vs. UTCI

ESM 1b: Responses averaged over values after 30, 60, 90 and 120 min vs. UTCI for the Reference Conditions only

ESM 1c: Early (30 min) and late (120 min) responses vs. UTCI for the Reference Conditions



averaged over responses after 30, 60, 90 and 120 min
(Box-Plots with joined medians derived with UTCI rounded to 2 K wide bins)



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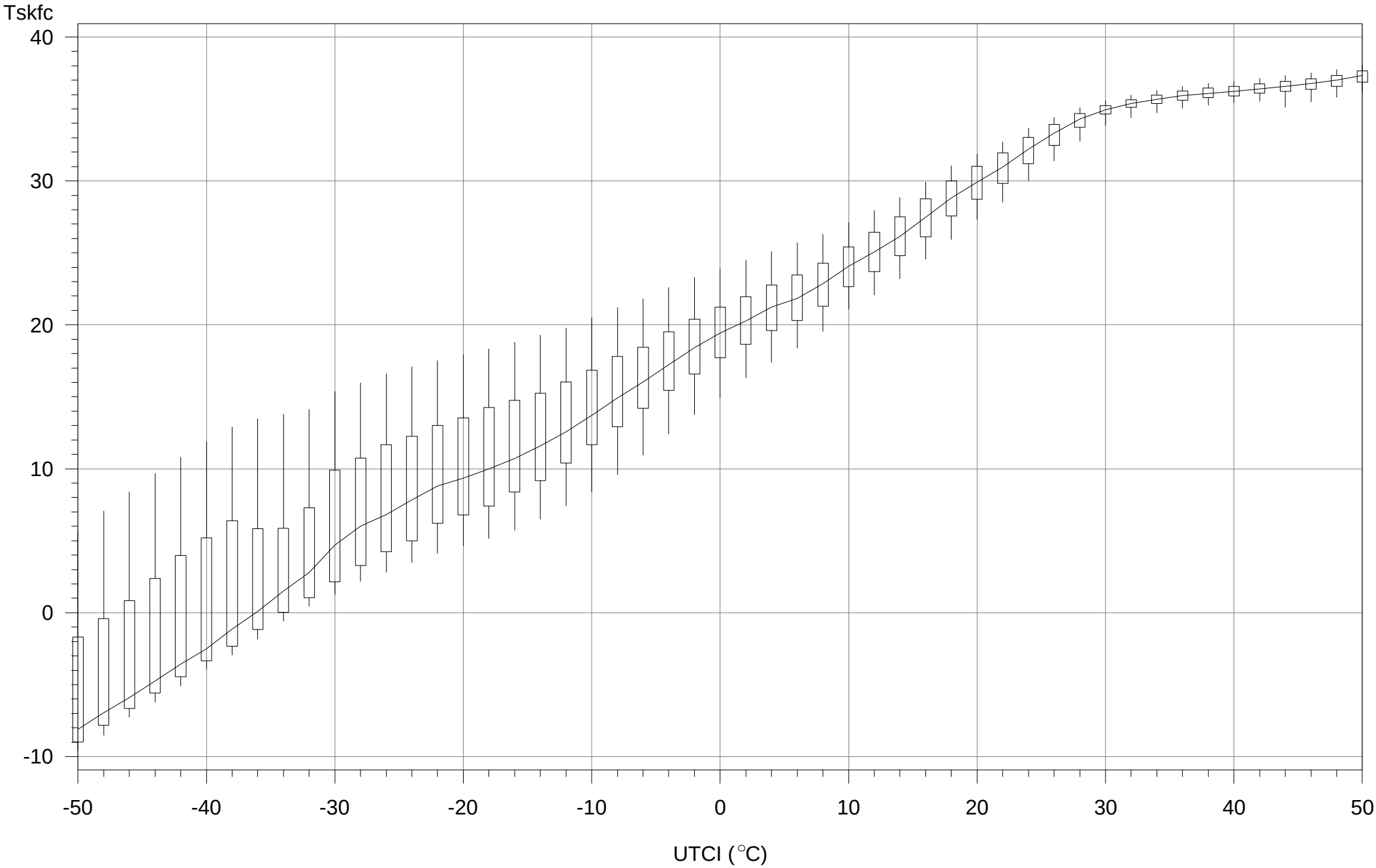

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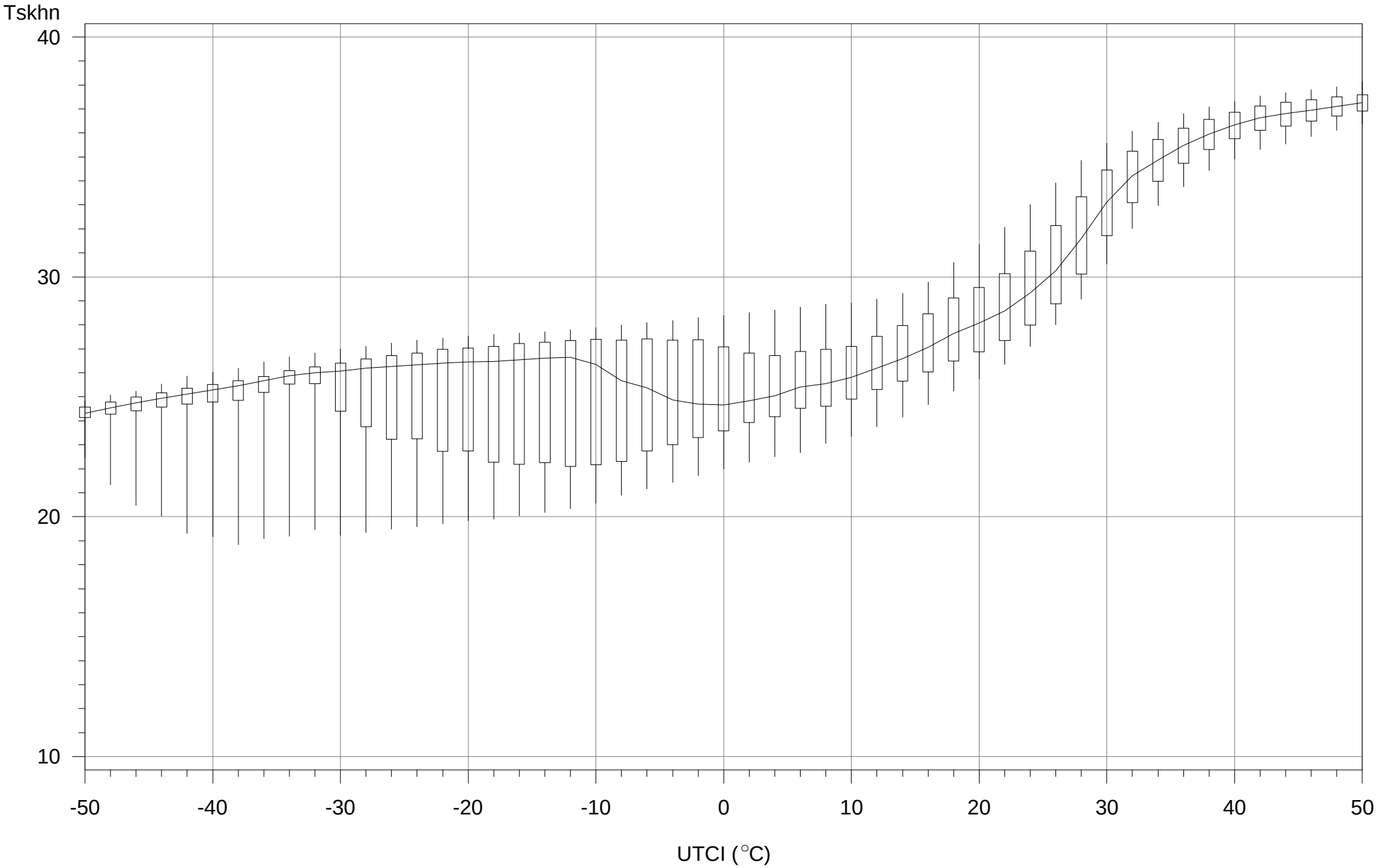

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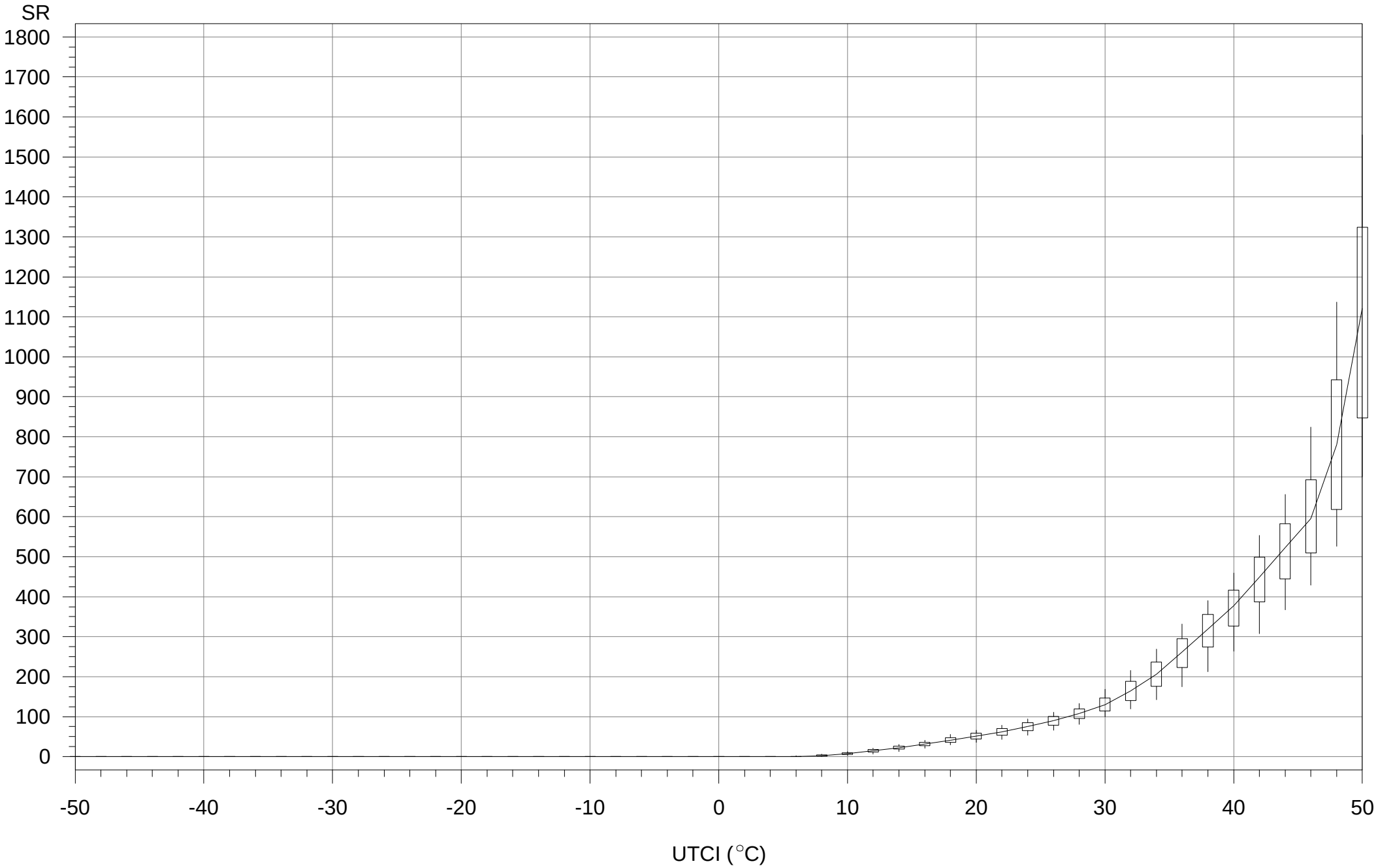

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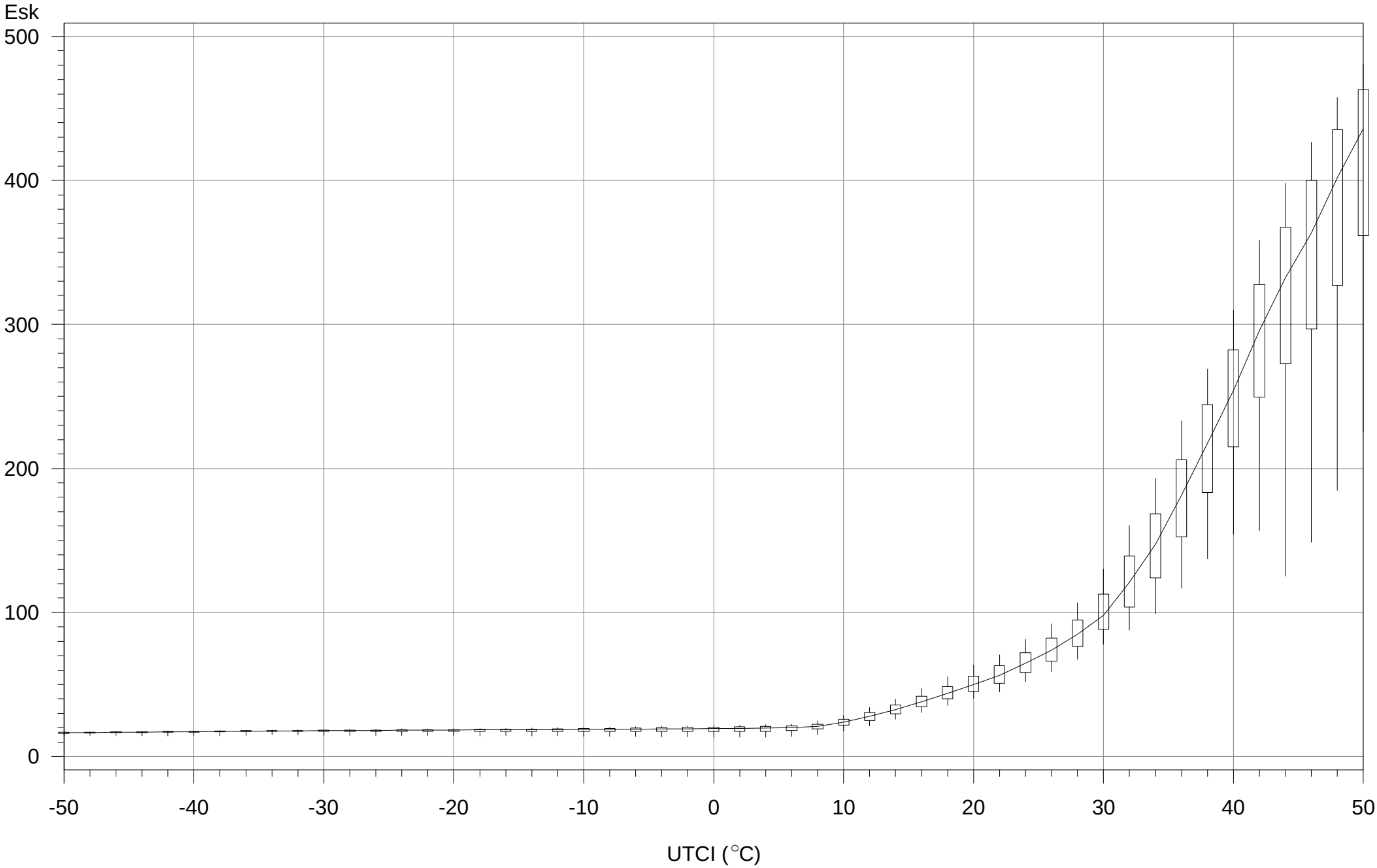

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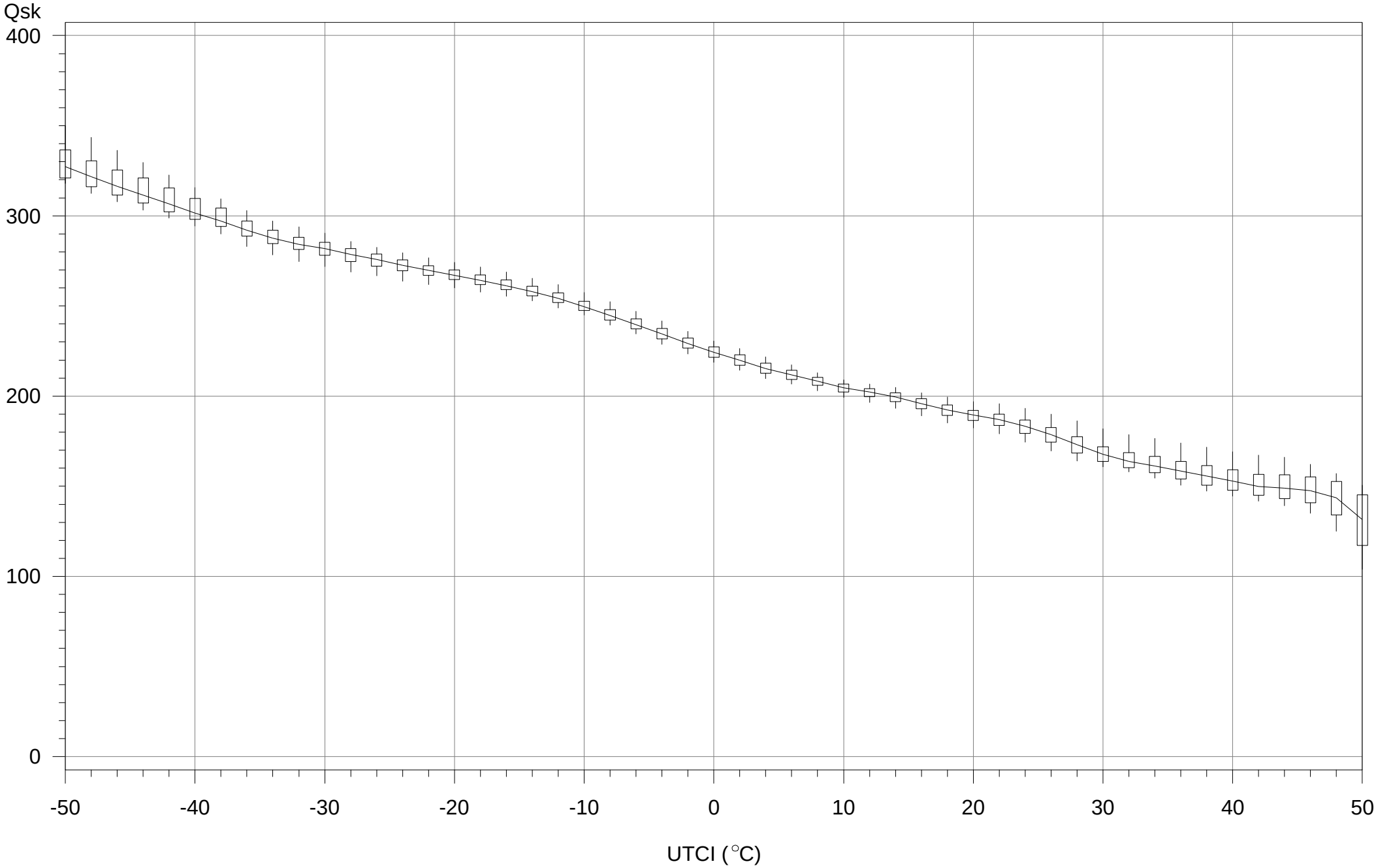

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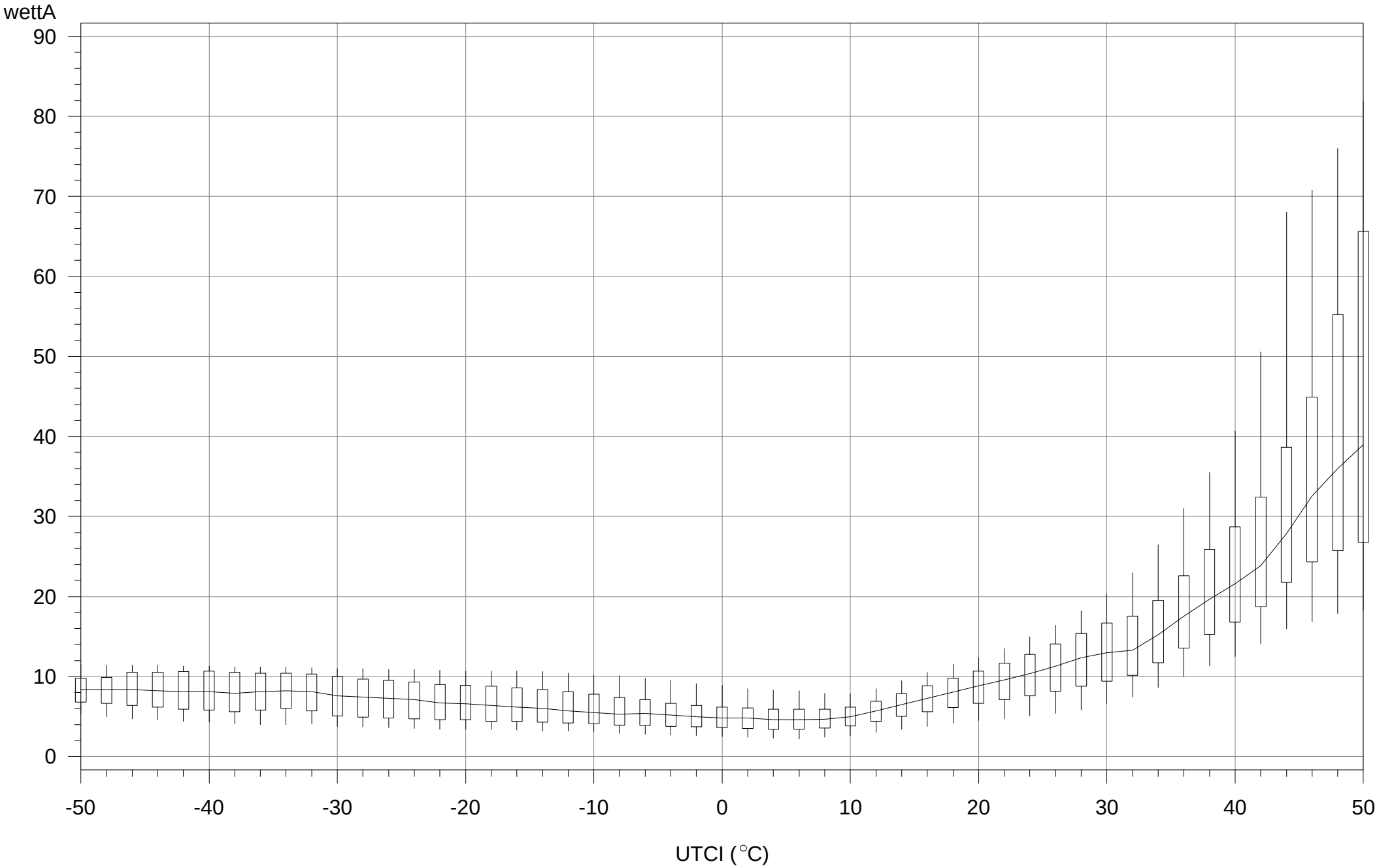

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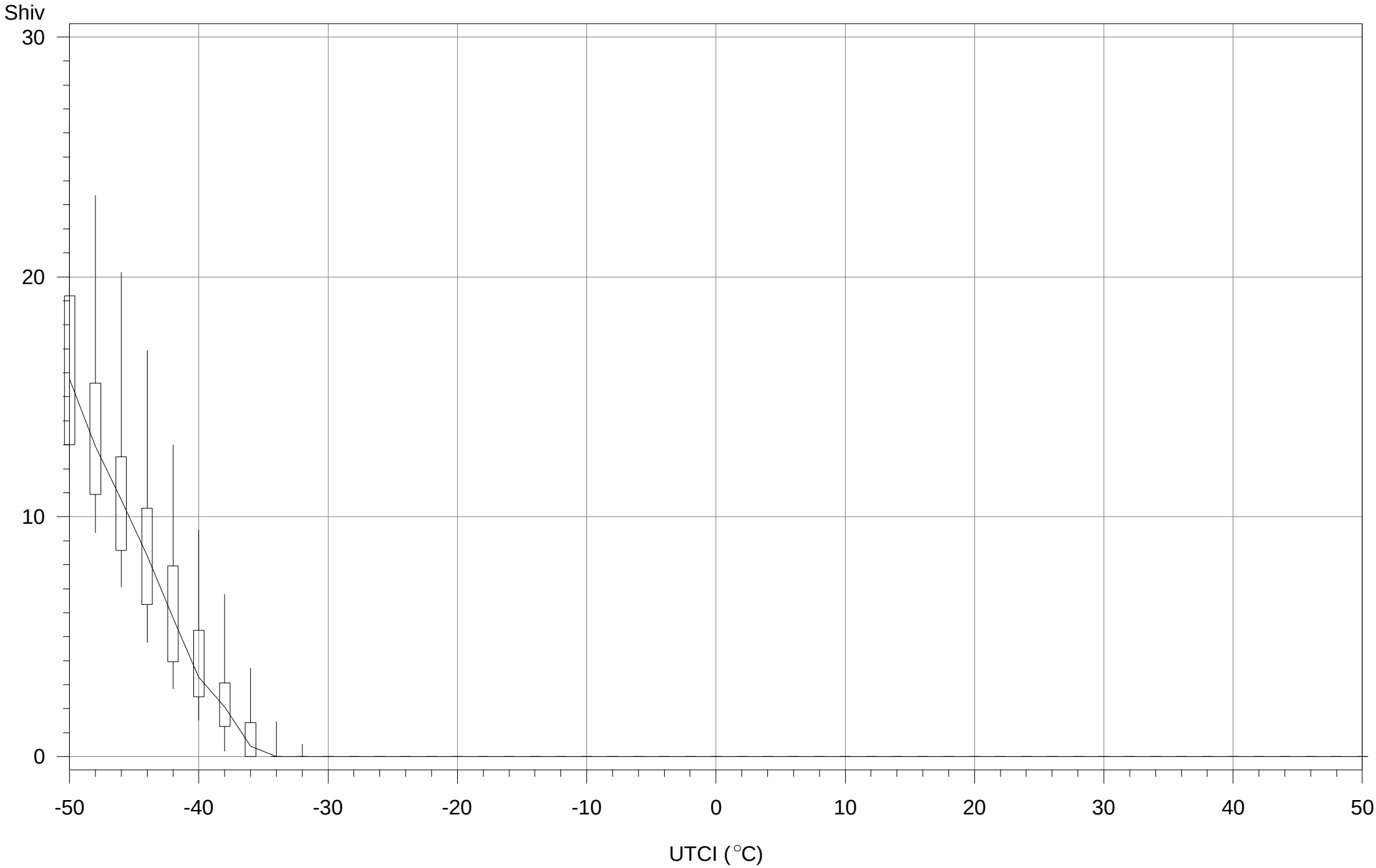

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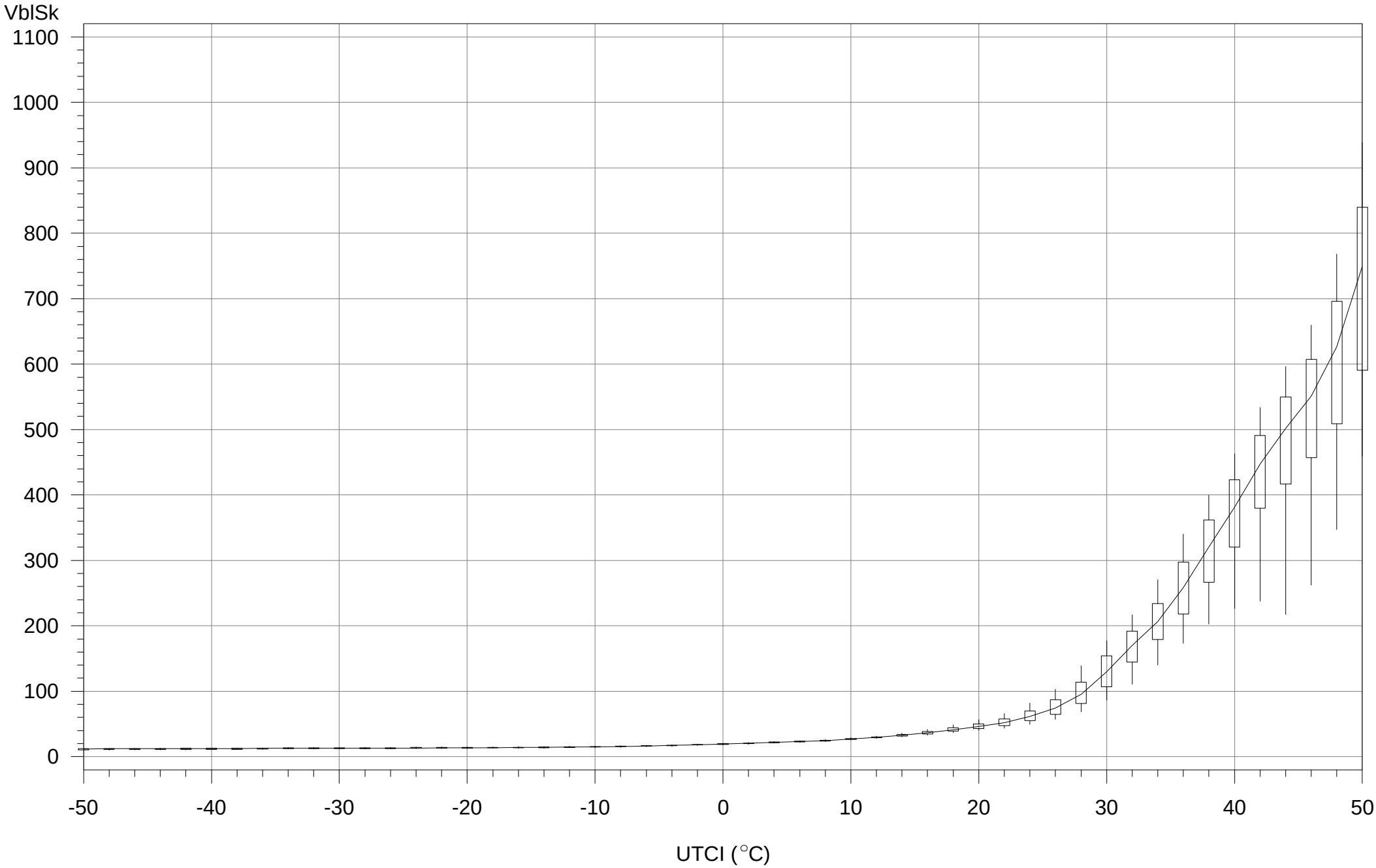

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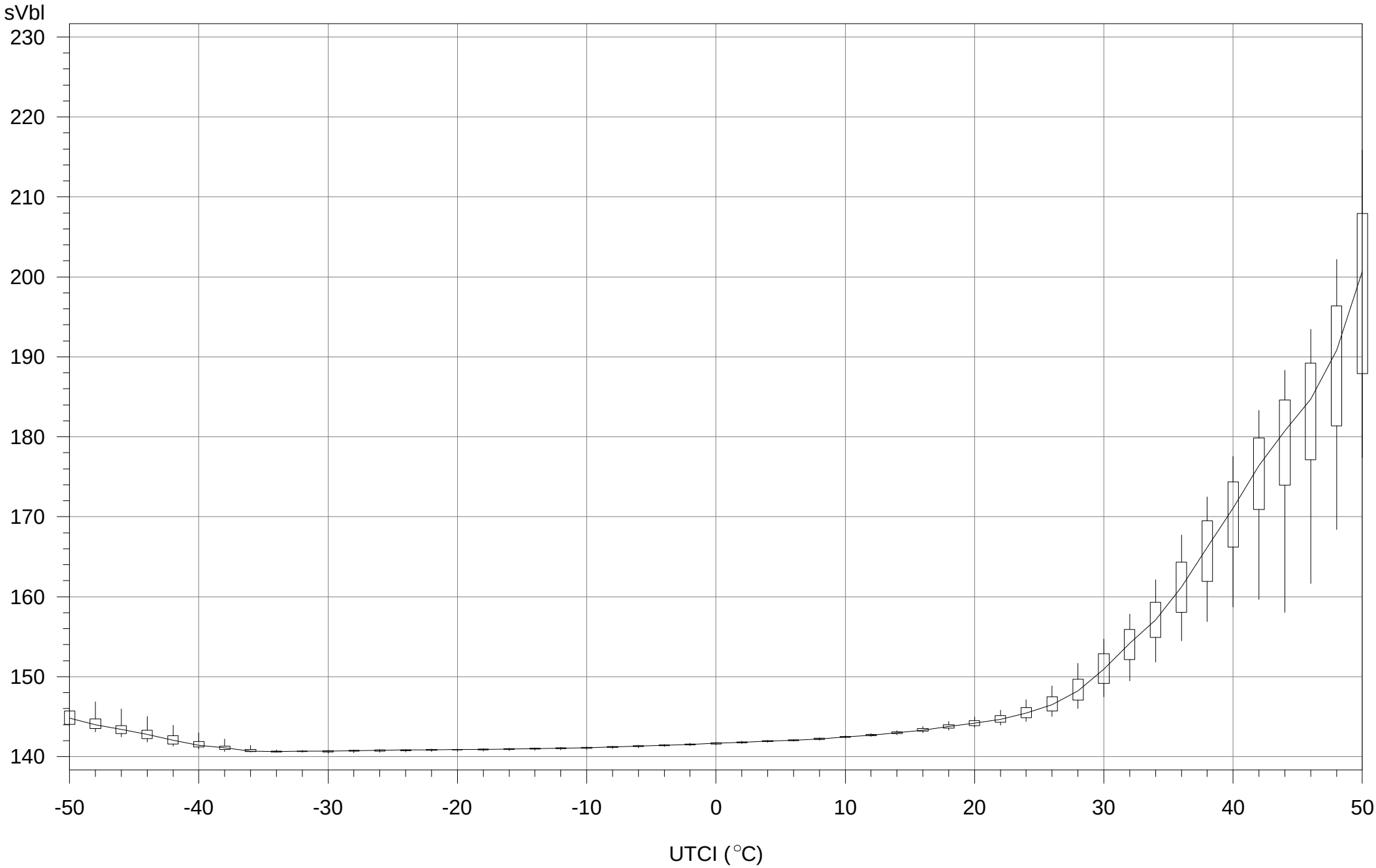

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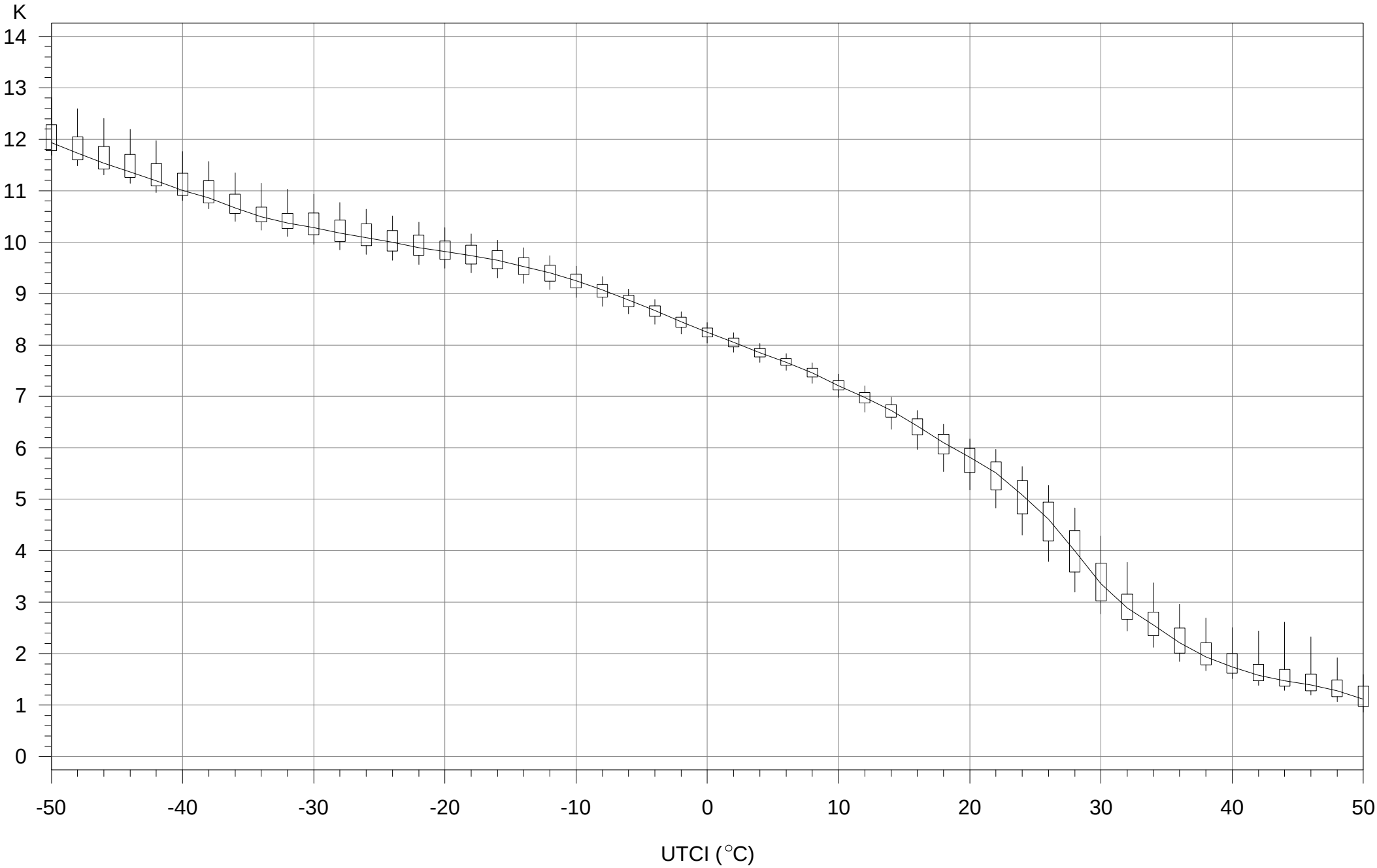

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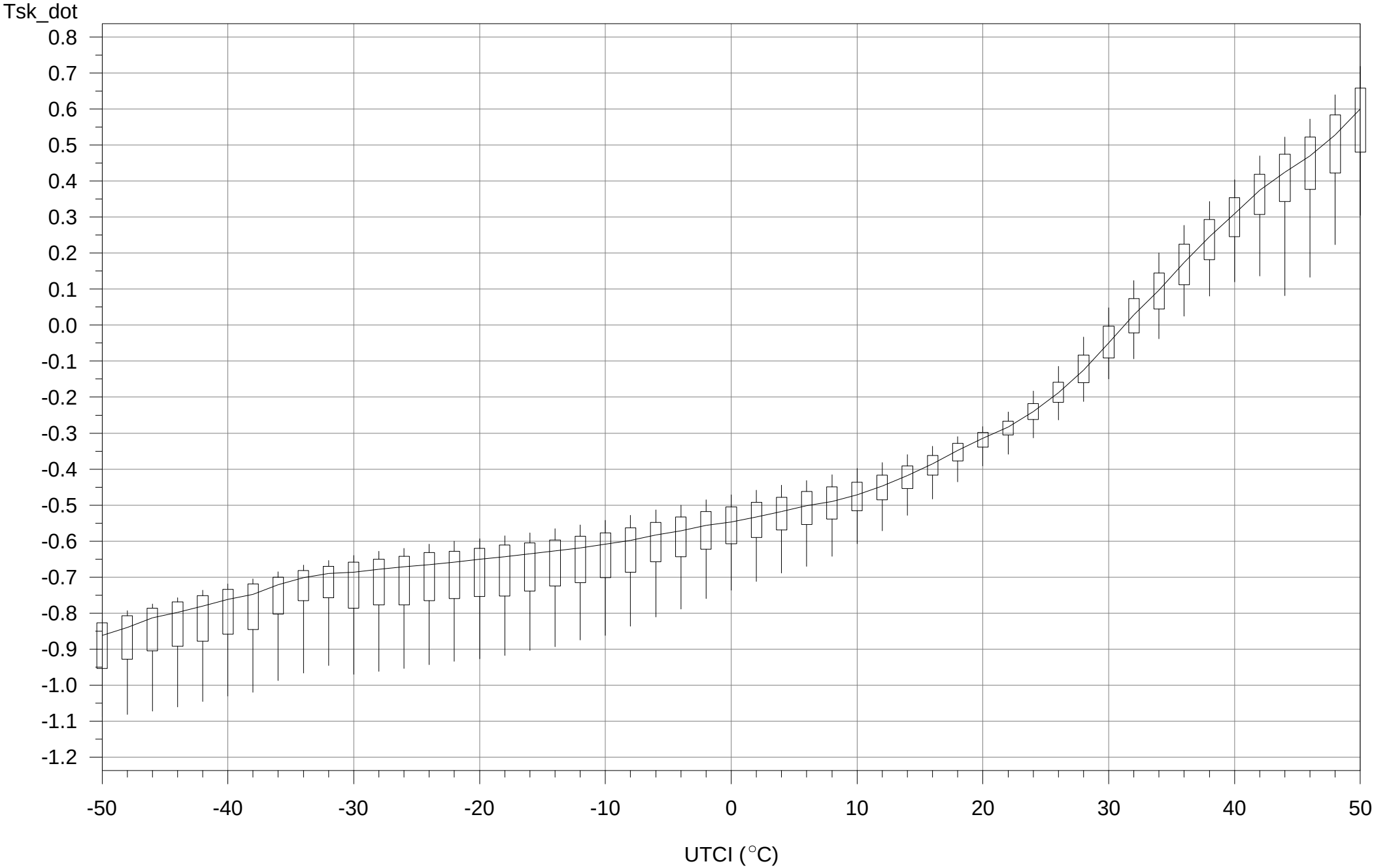

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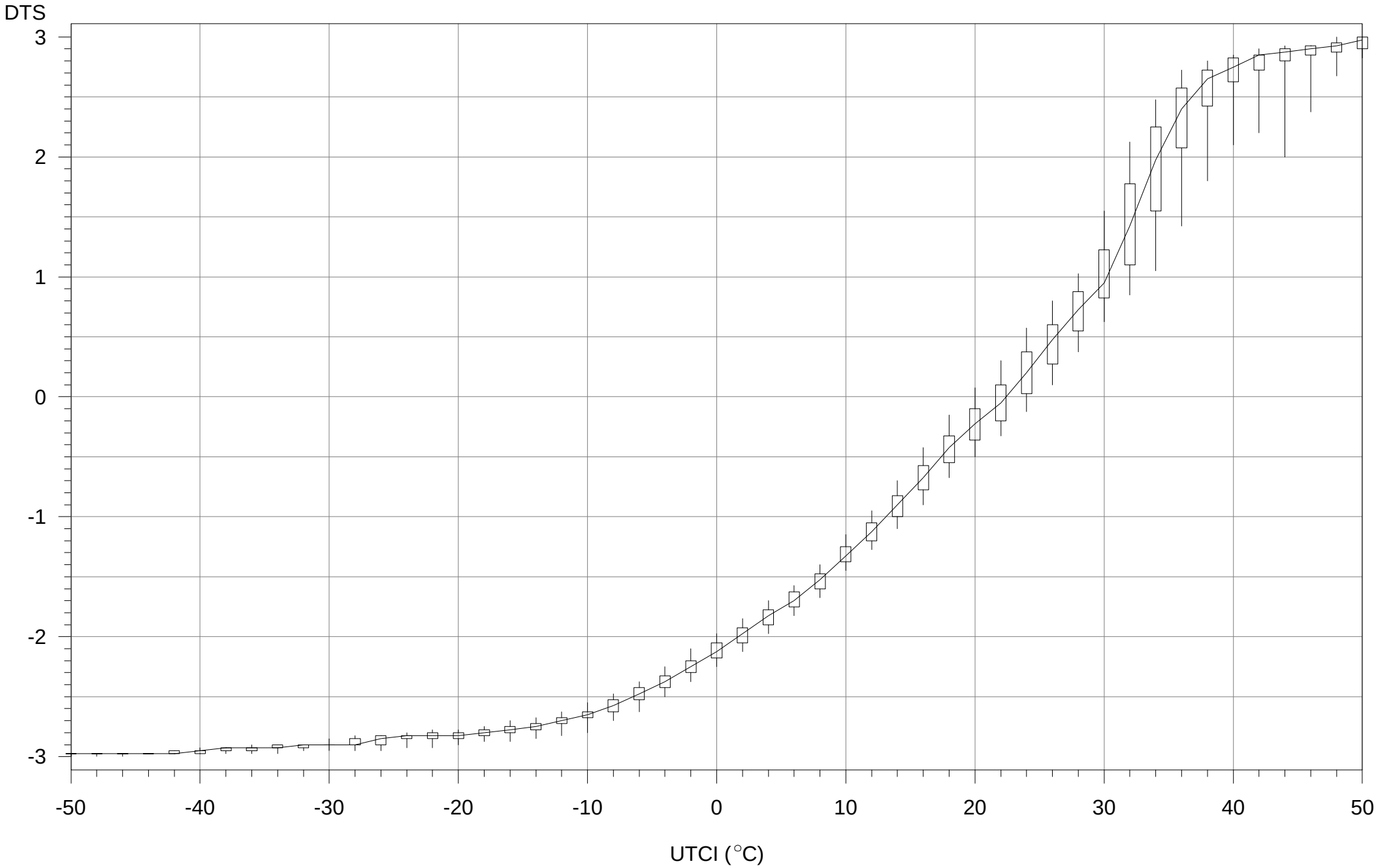
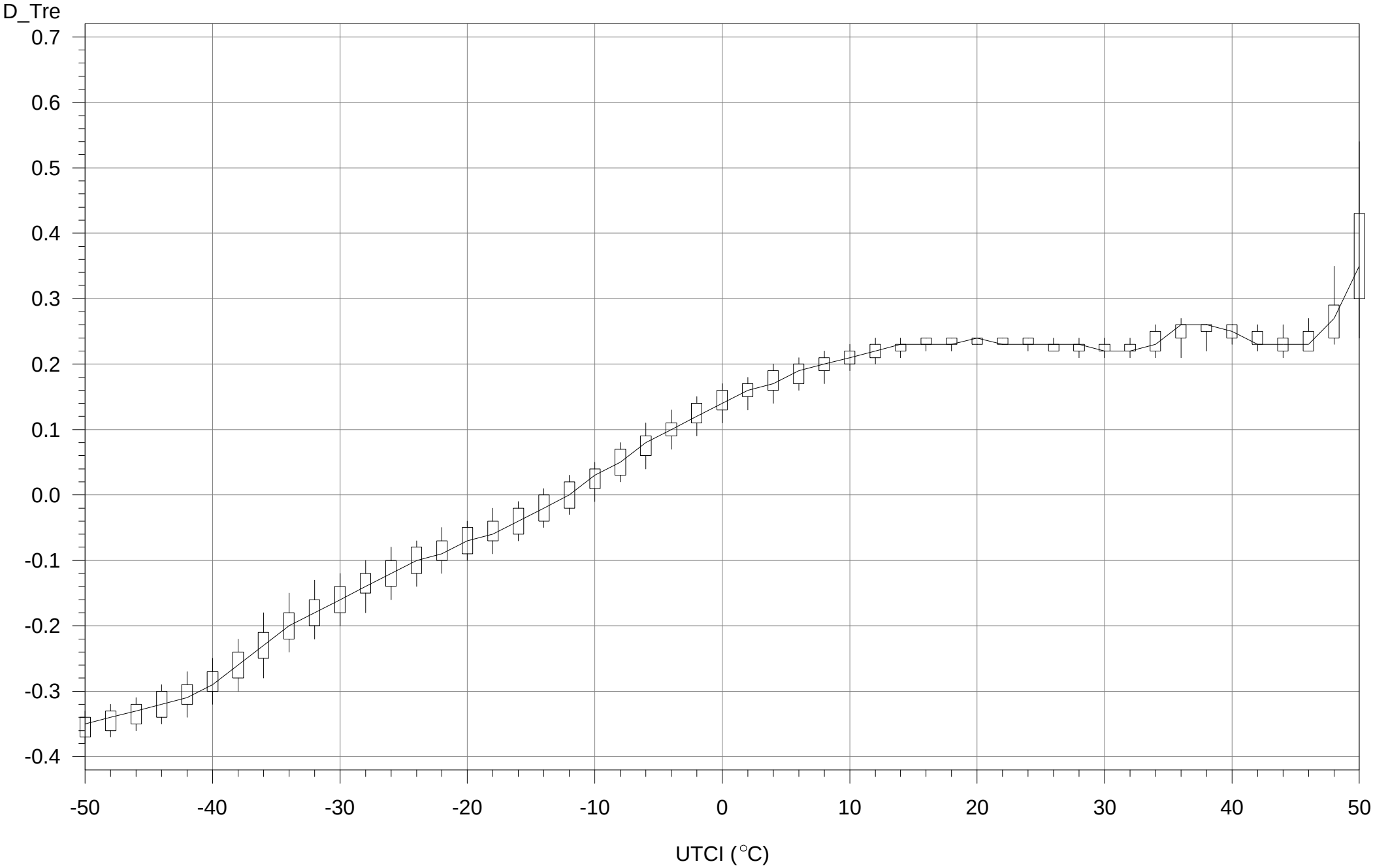
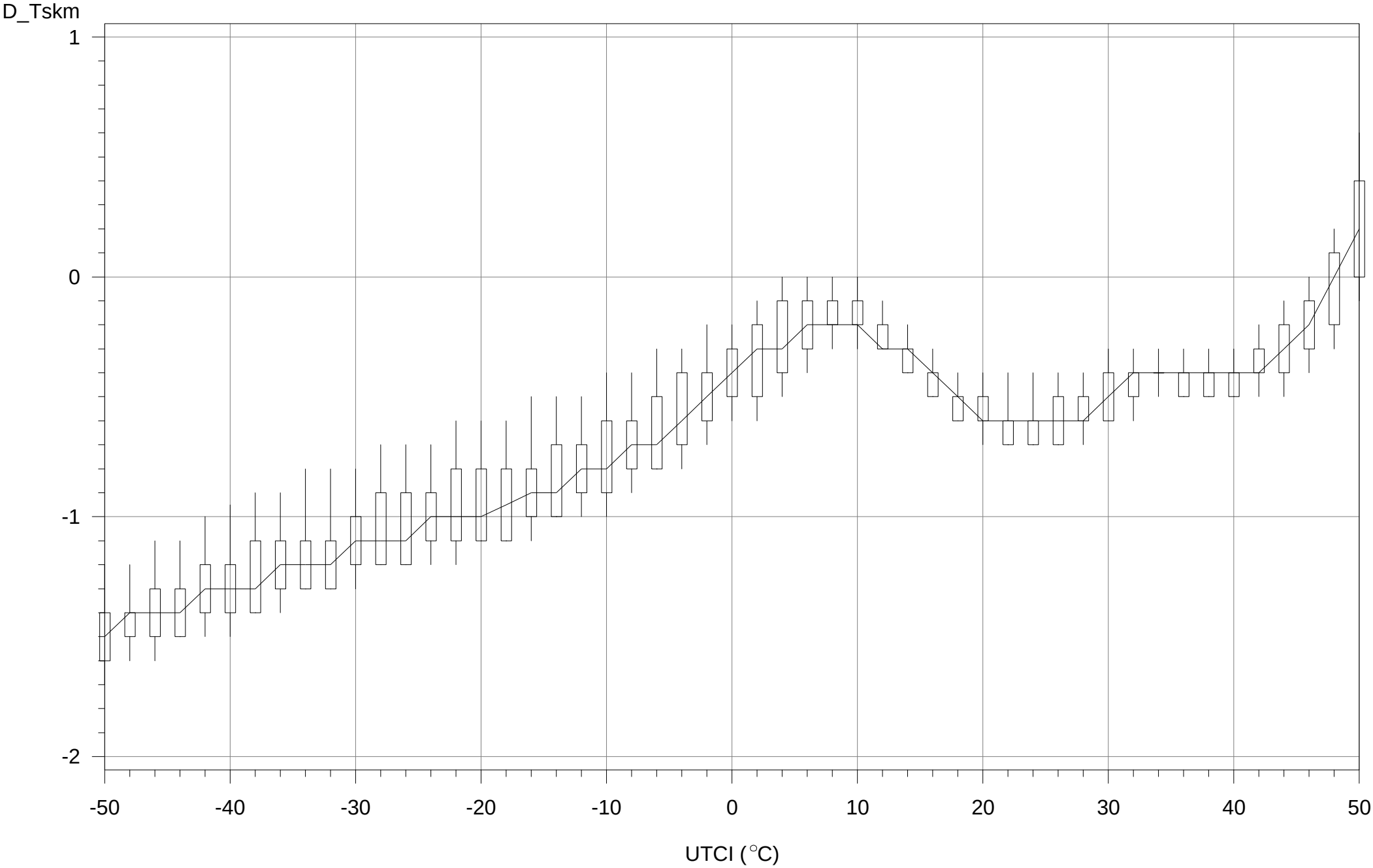


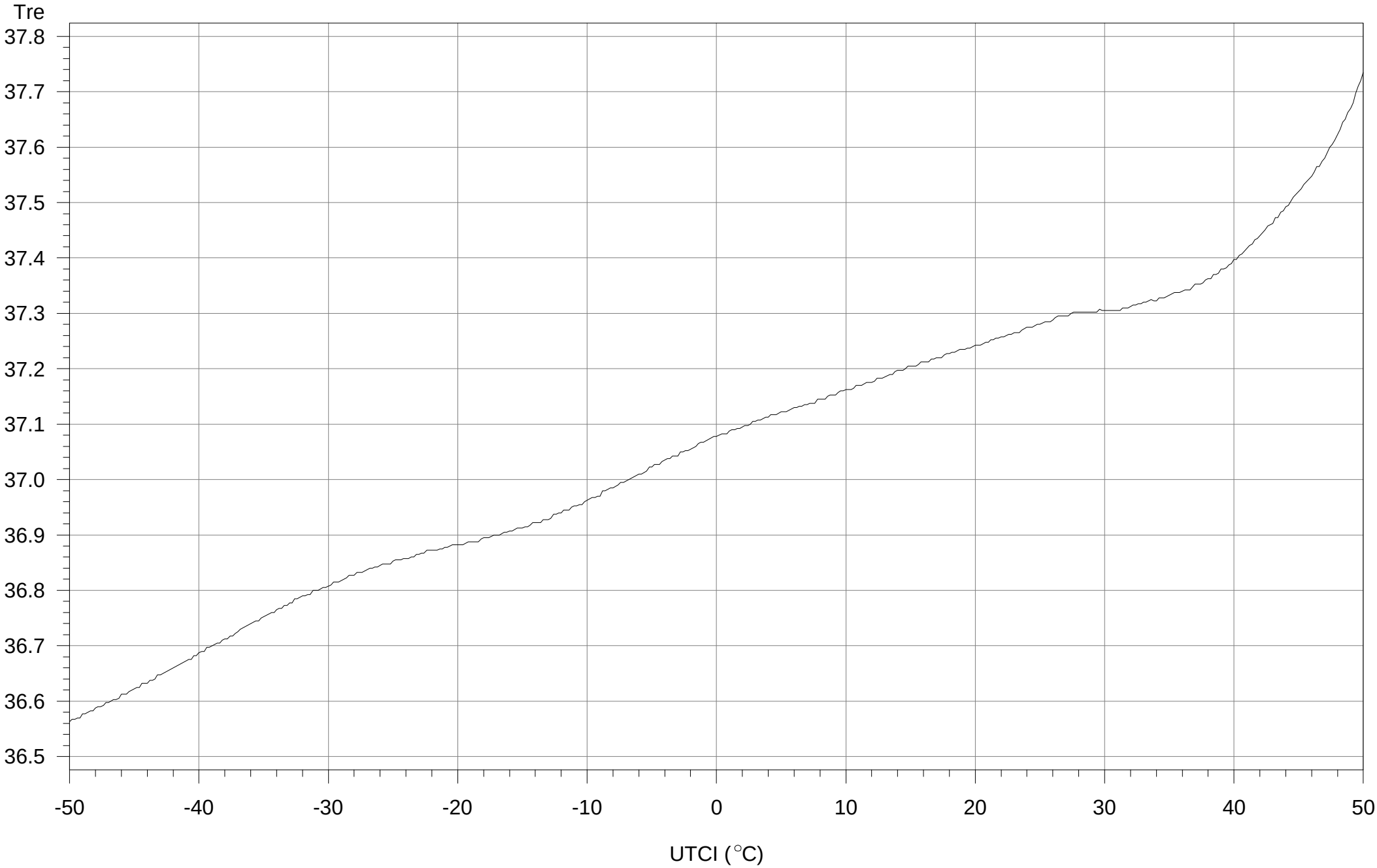
averaged over responses after 30, 60, 90 and 120 min
(Box-Plots with joined medians derived with UTCI rounded to 2 K wide bins)



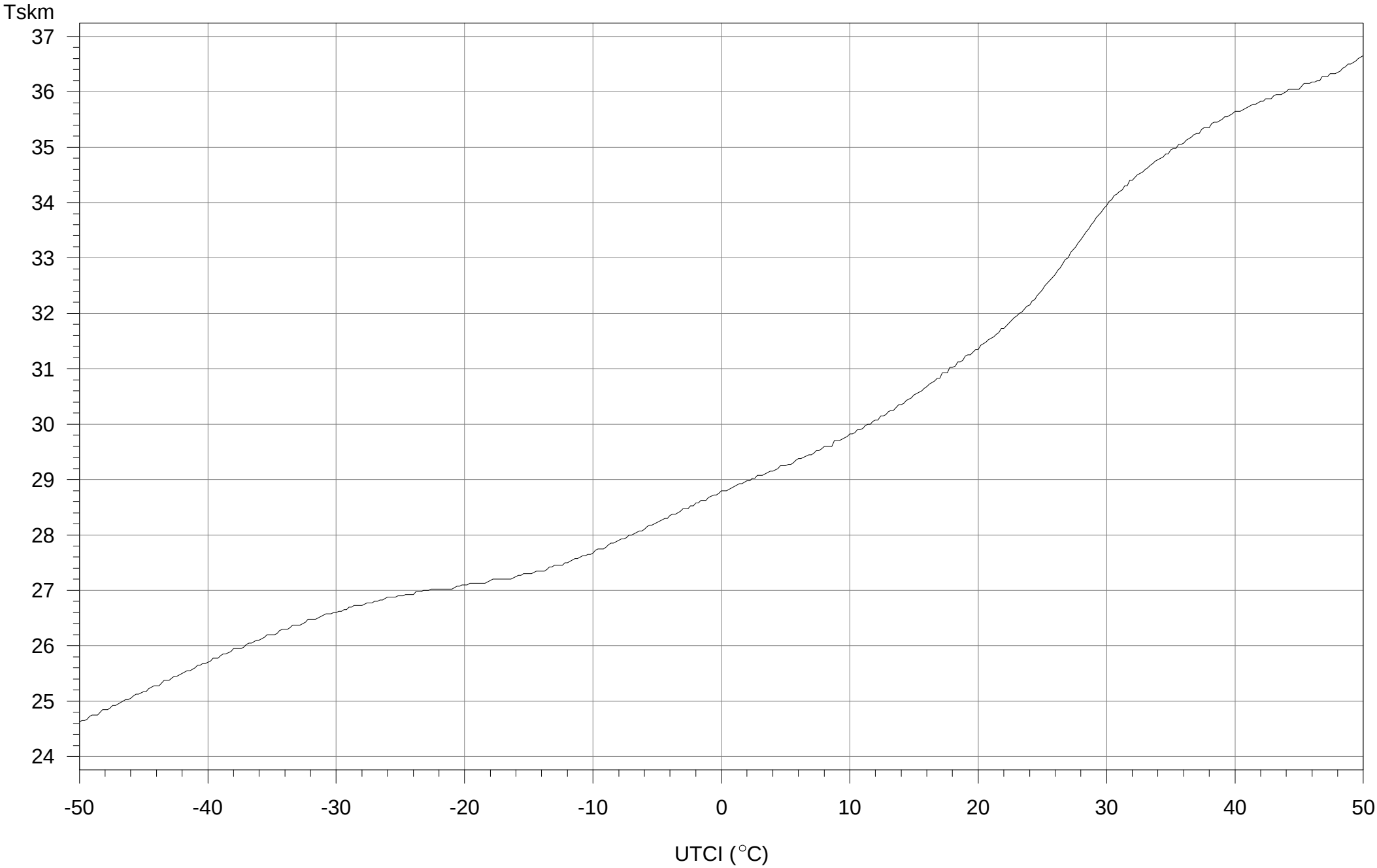
Time gradient of rectal temperature Tre_120 - Tre_60 (K/h)
(Box-Plots with joined medians derived with UTCI rounded to 2 K wide bins)



Time gradient of mean skin temperature Tskm_120 - Tskm_60 (K/h)
(Box-Plots with joined medians derived with UTCI rounded to 2 K wide bins)



averaged over responses after 30, 60, 90 and 120 min
(for reference conditions)



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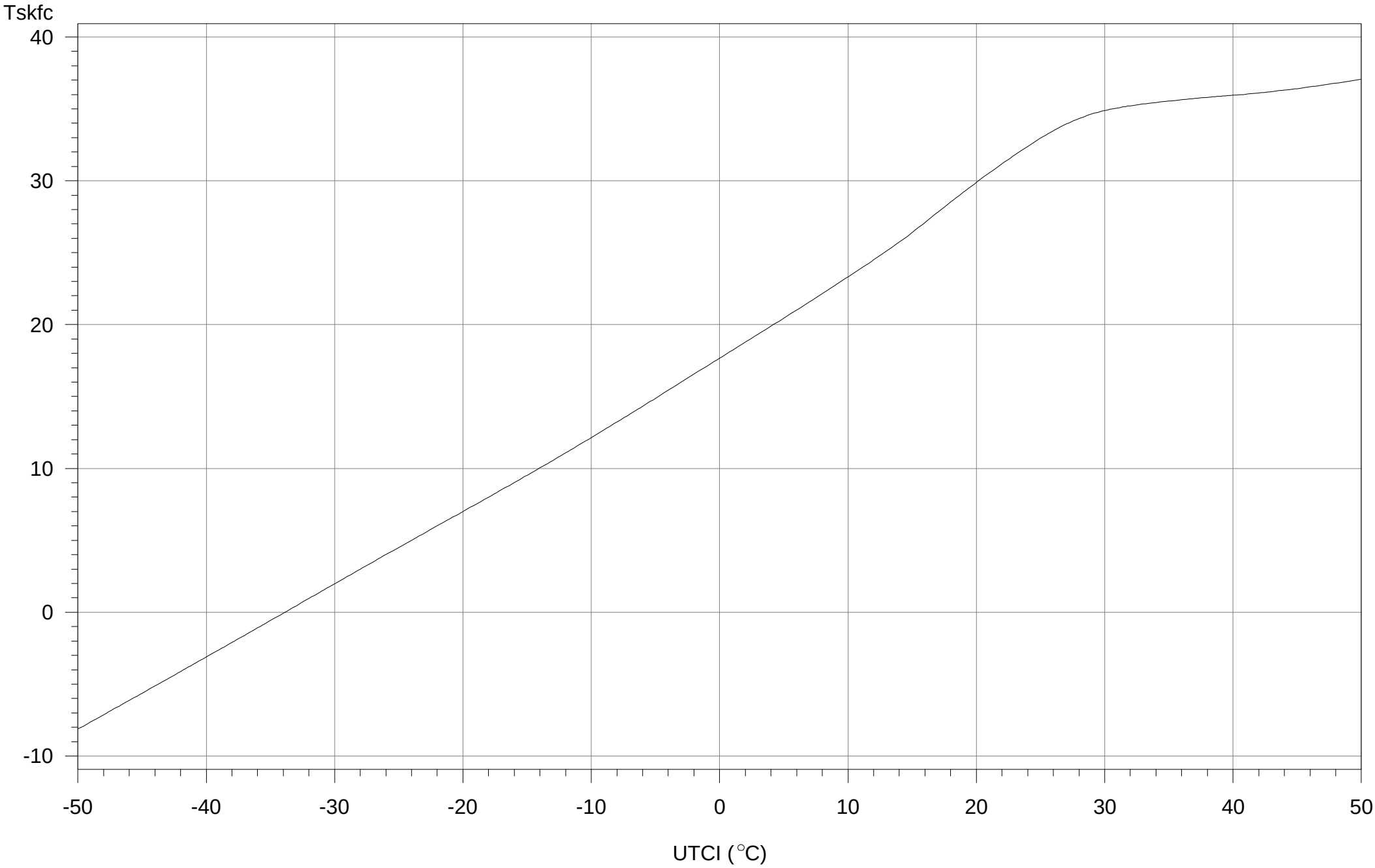

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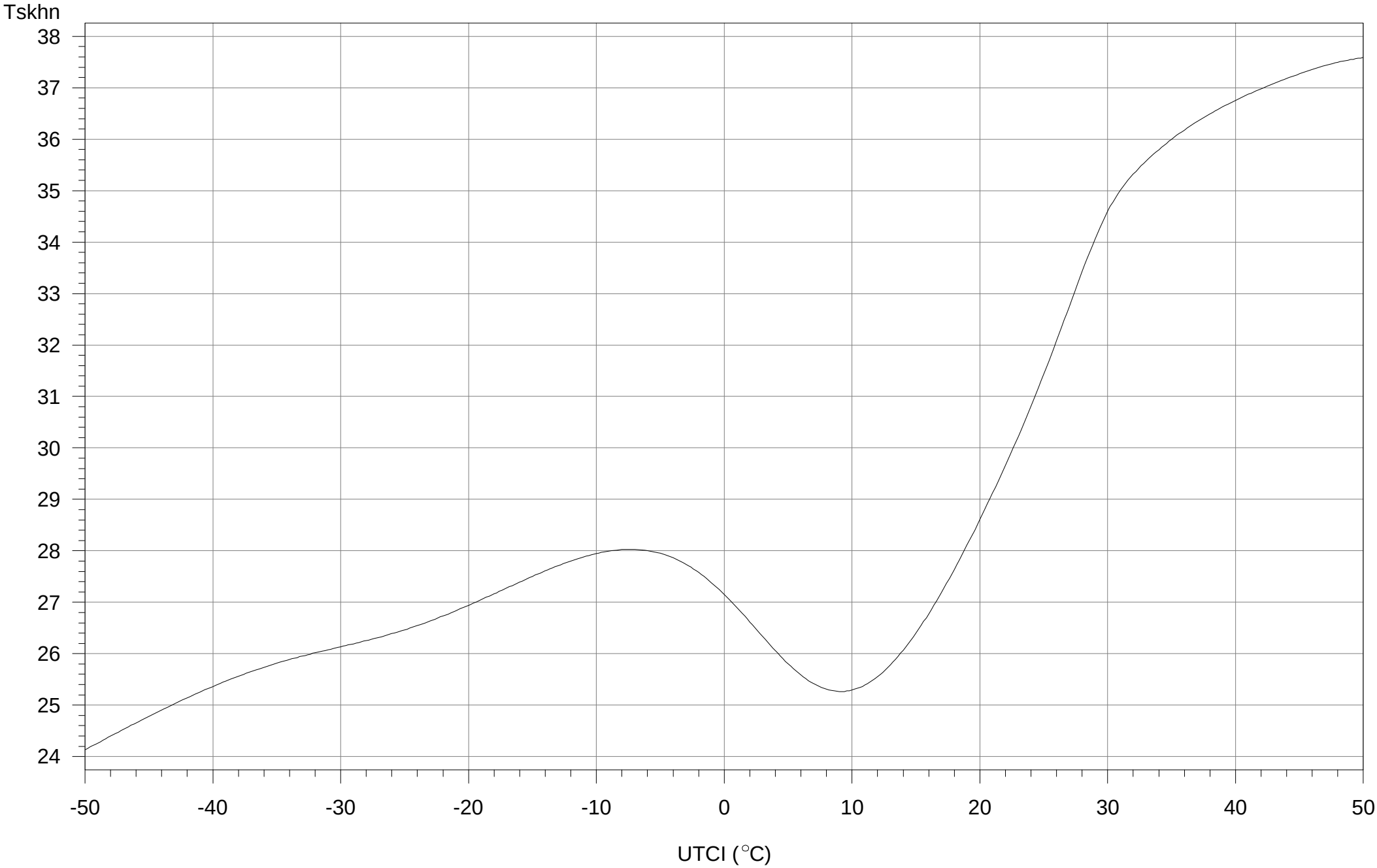

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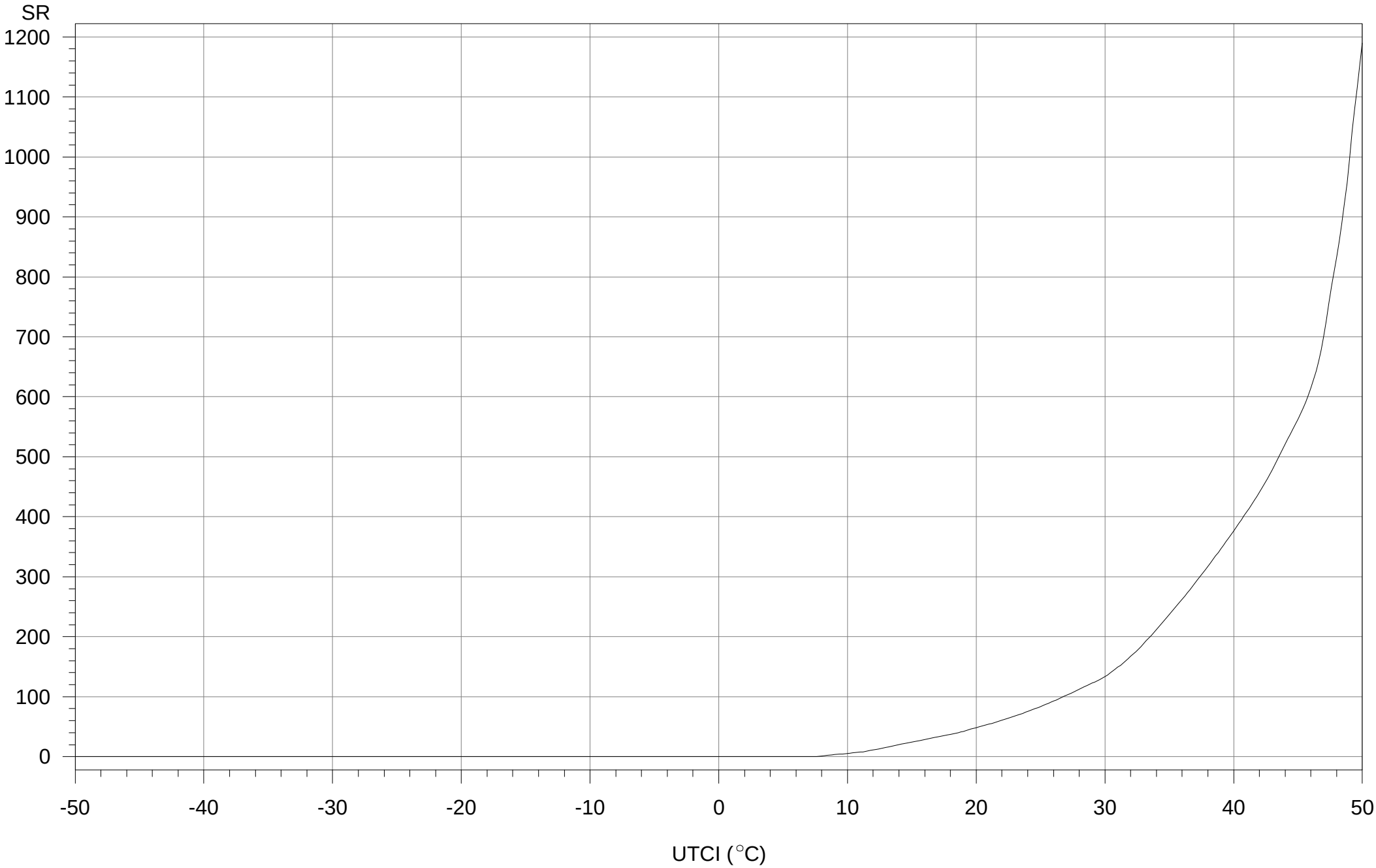

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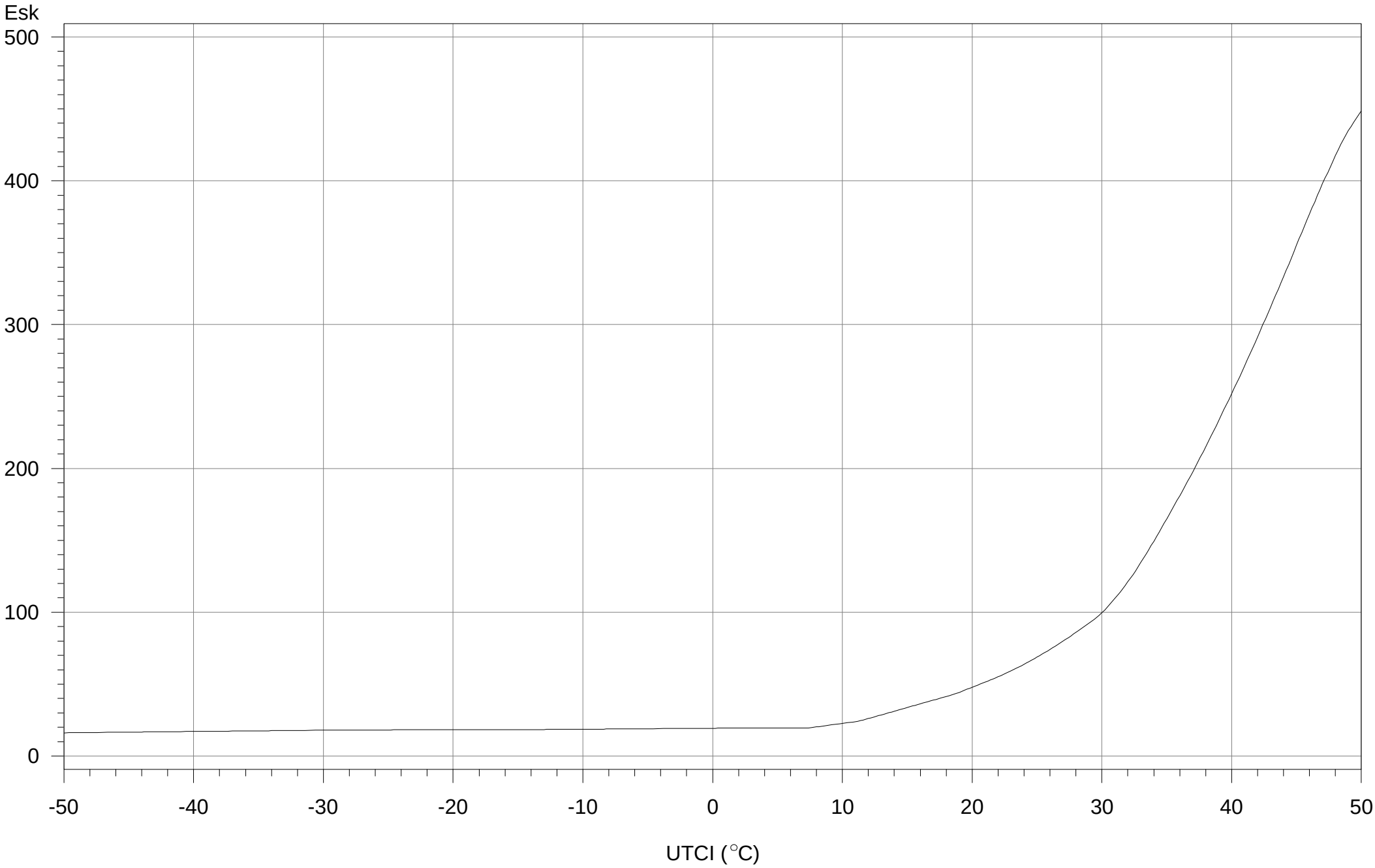

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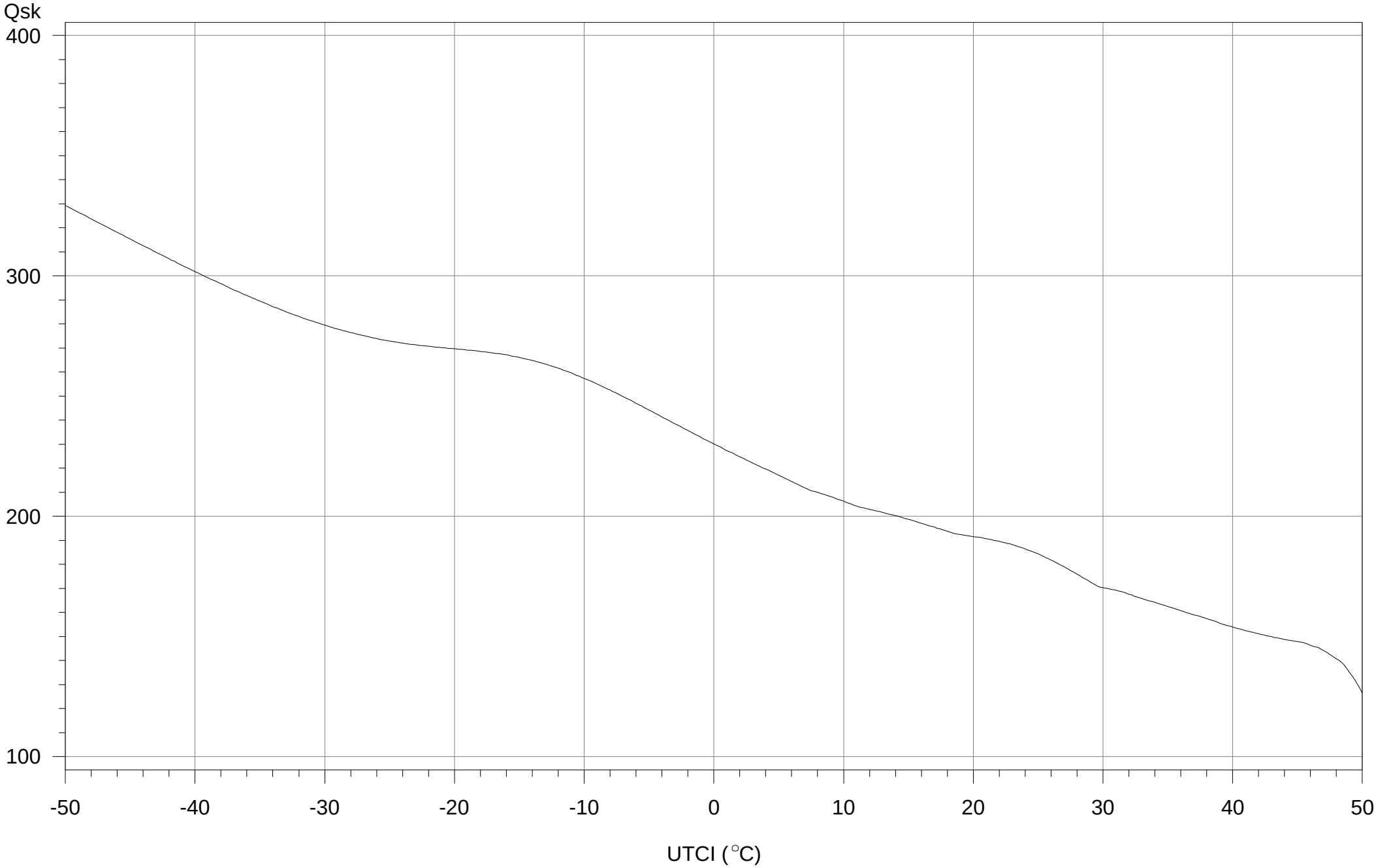

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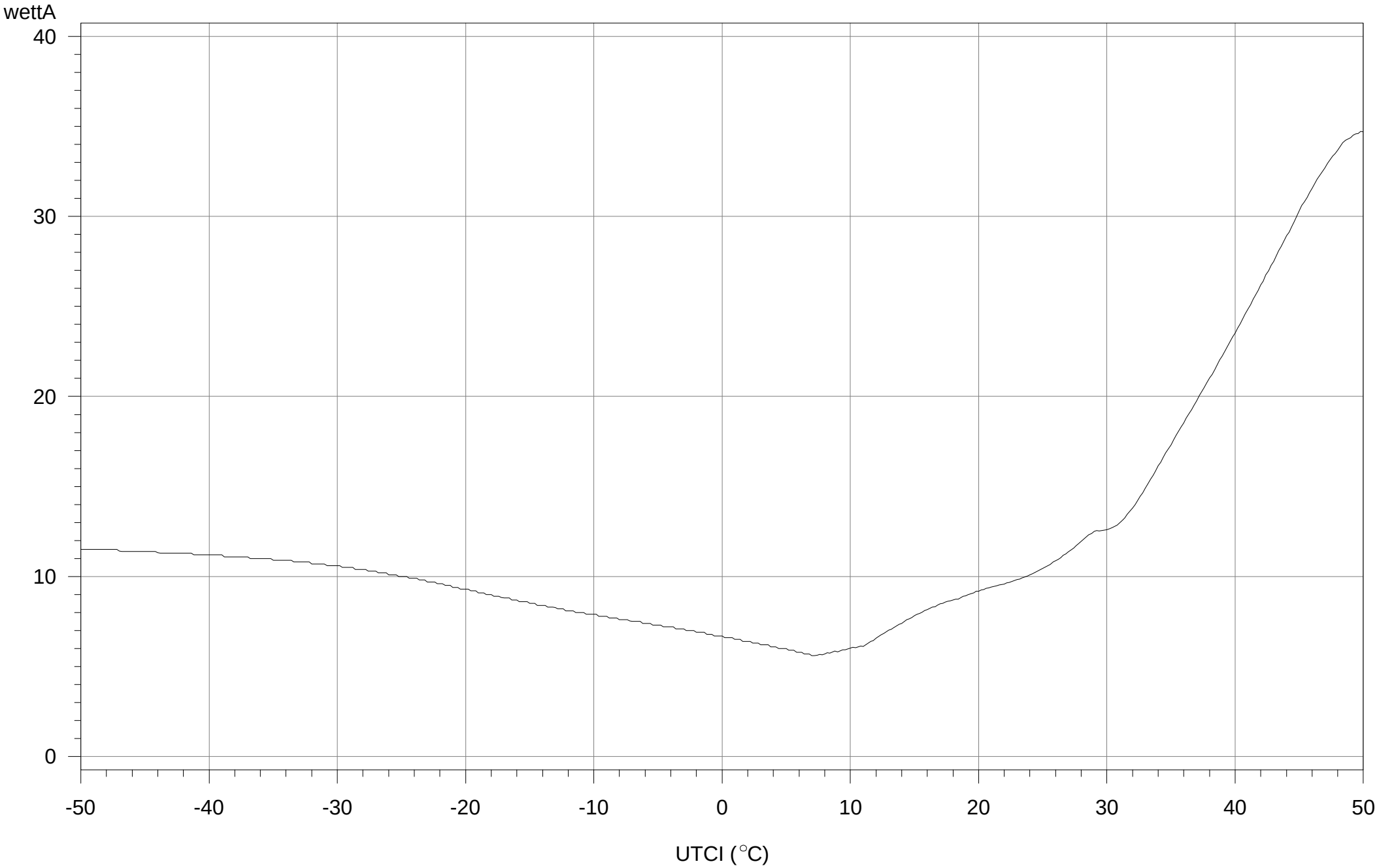

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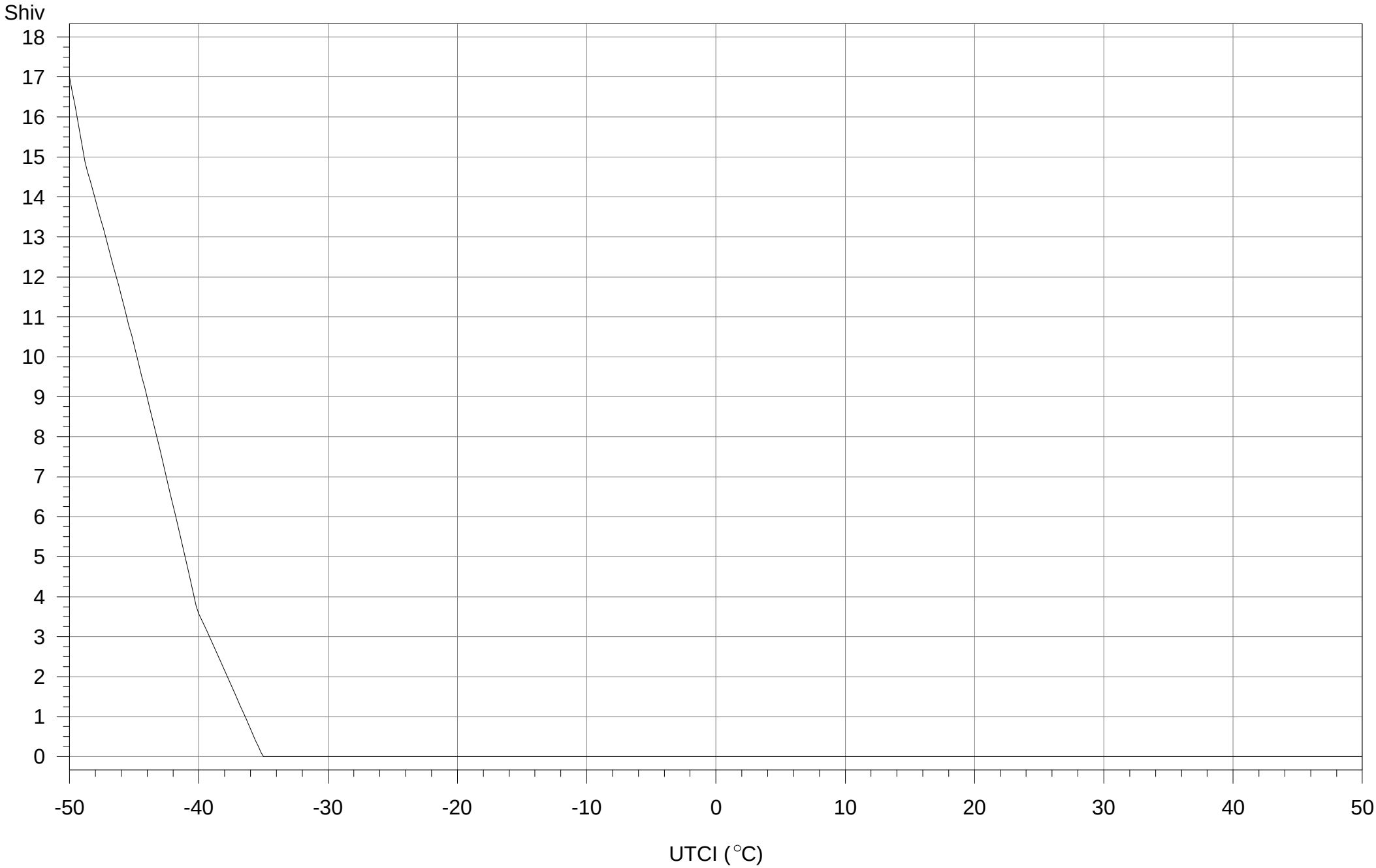

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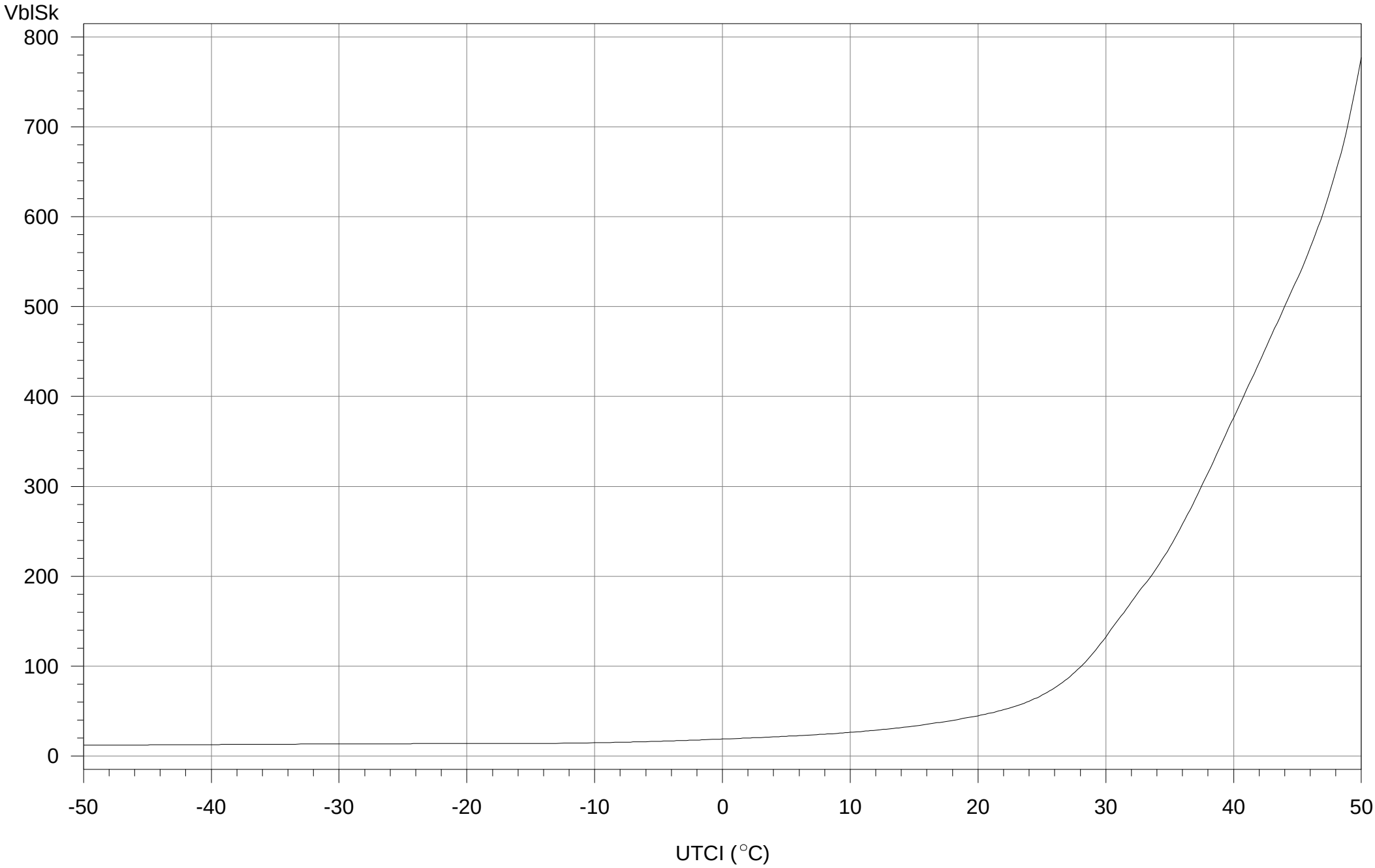

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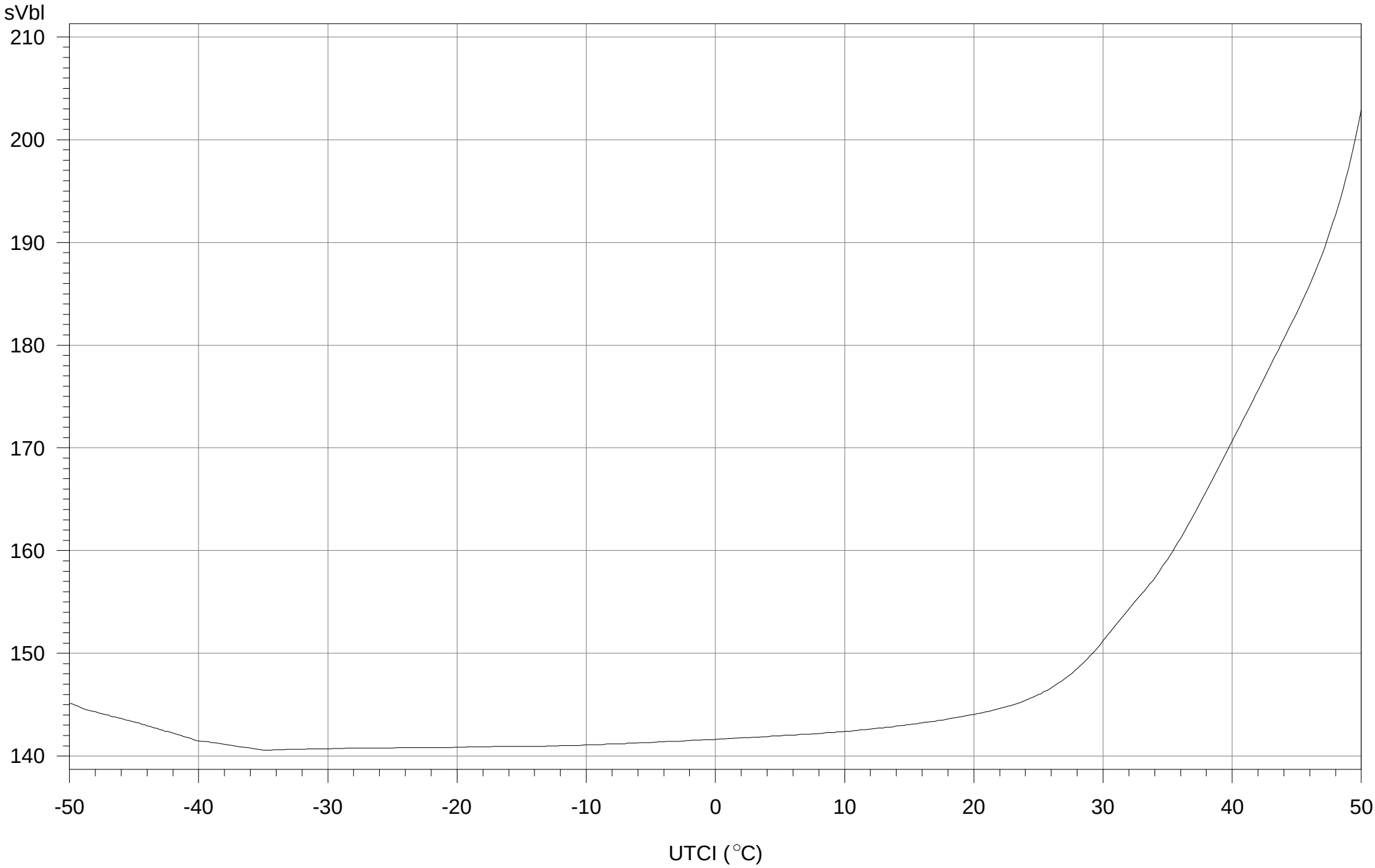

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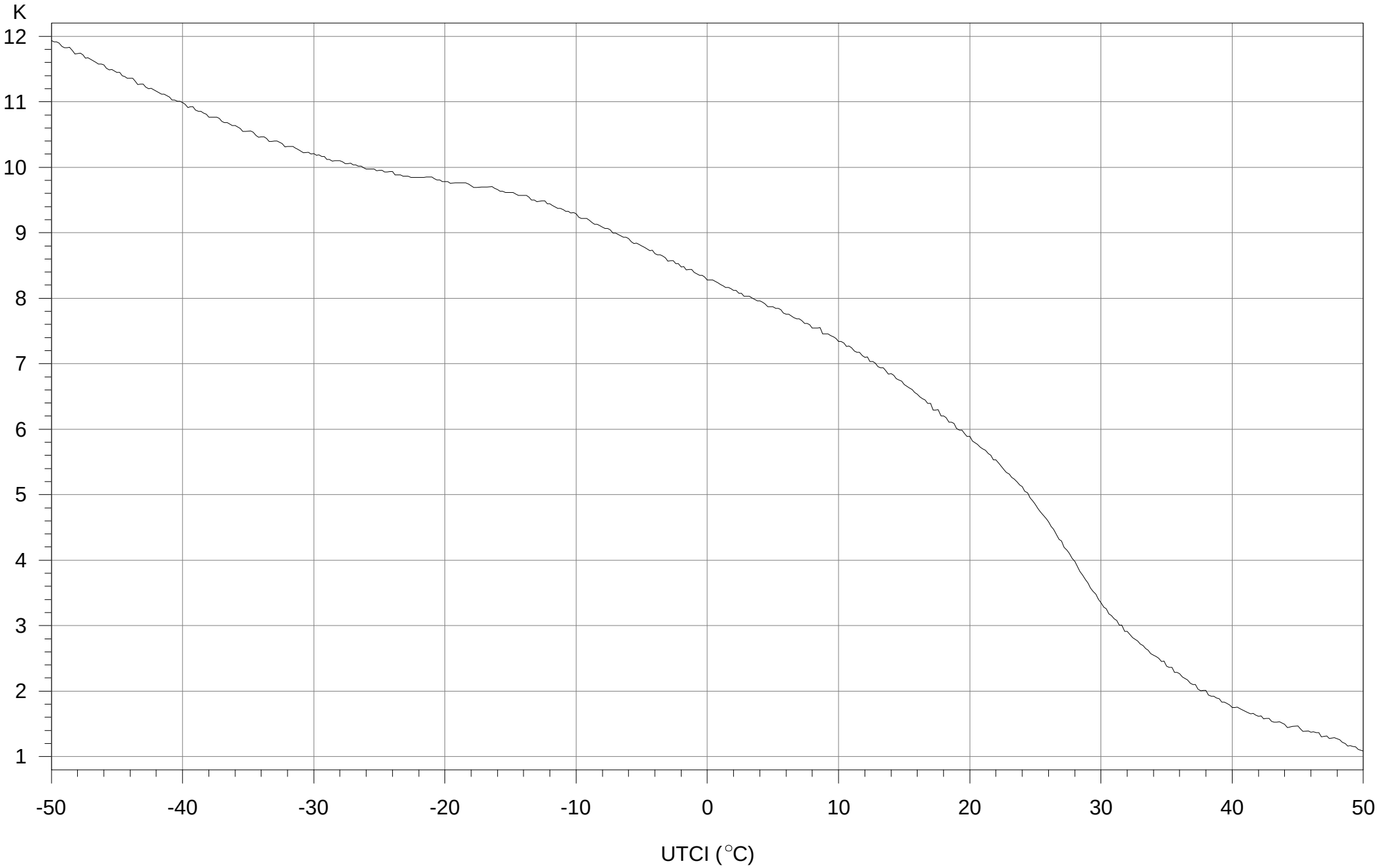

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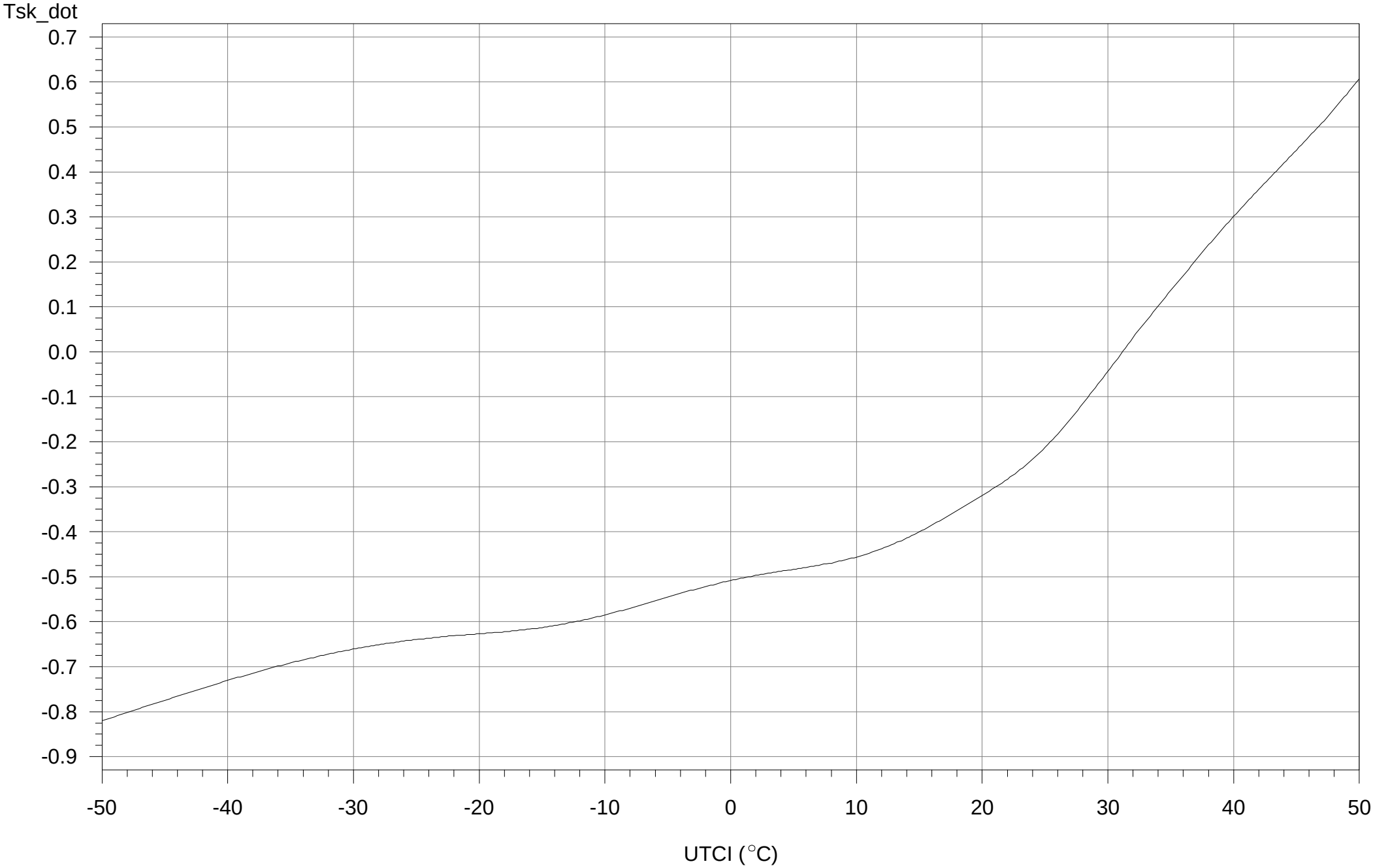
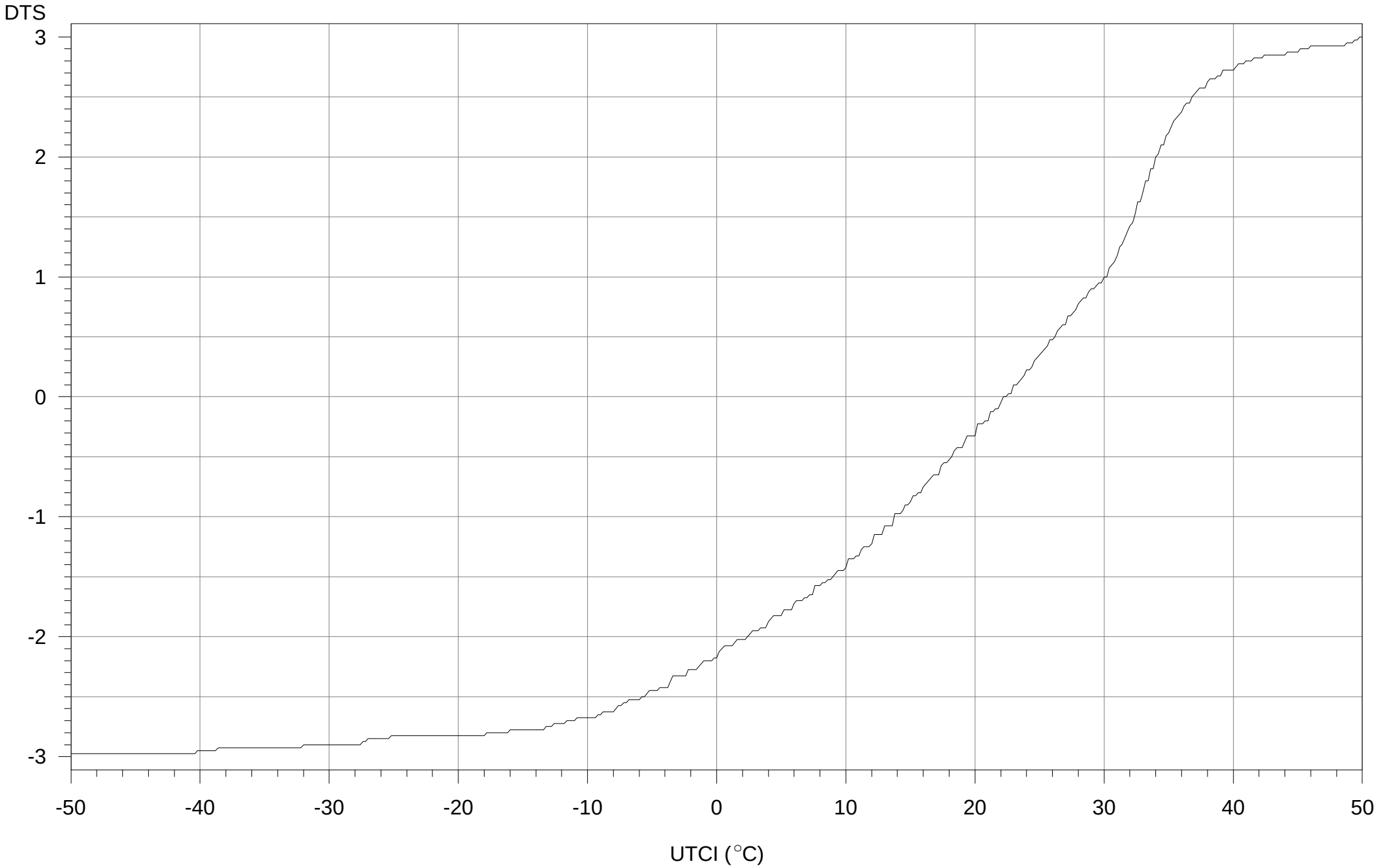
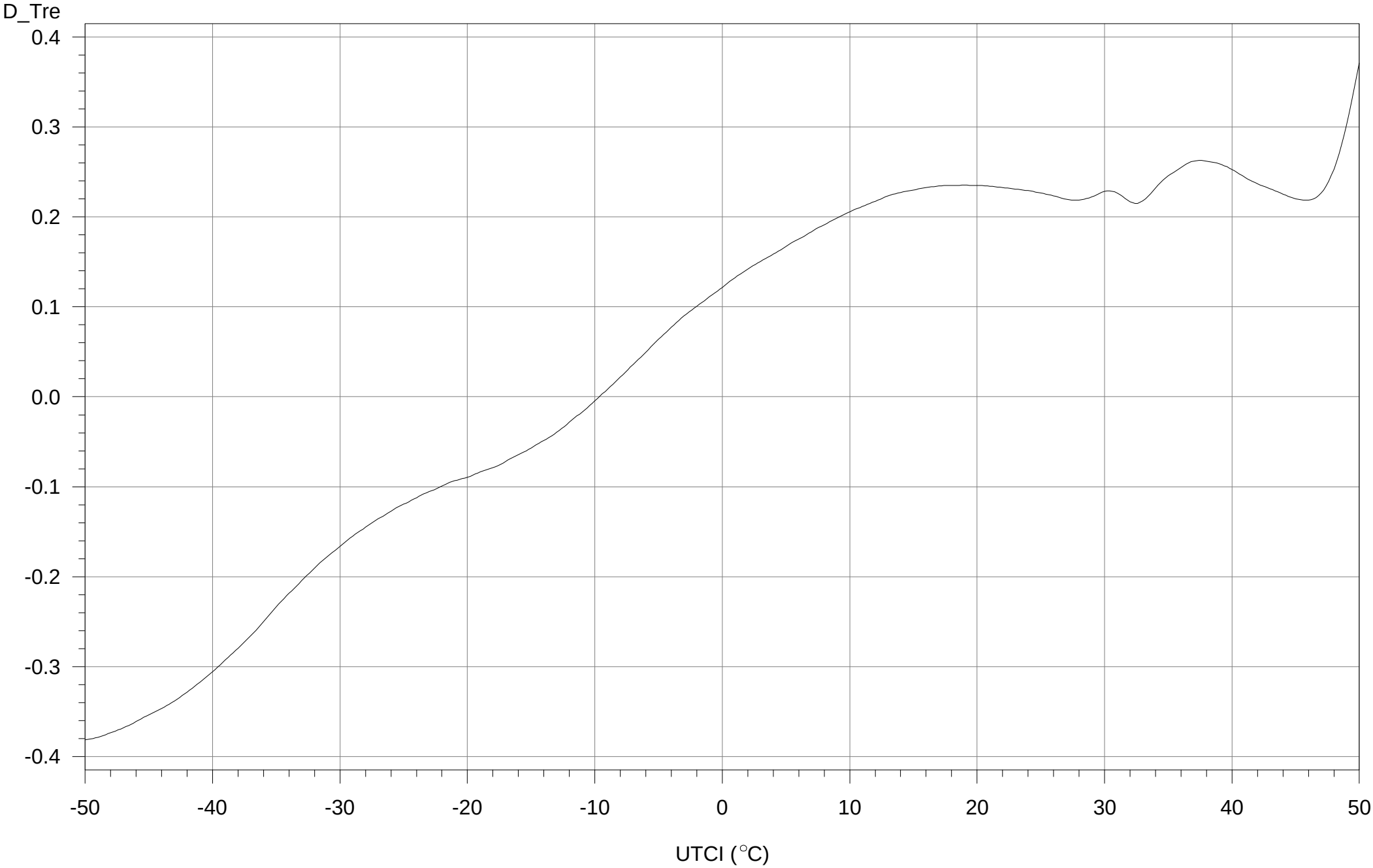


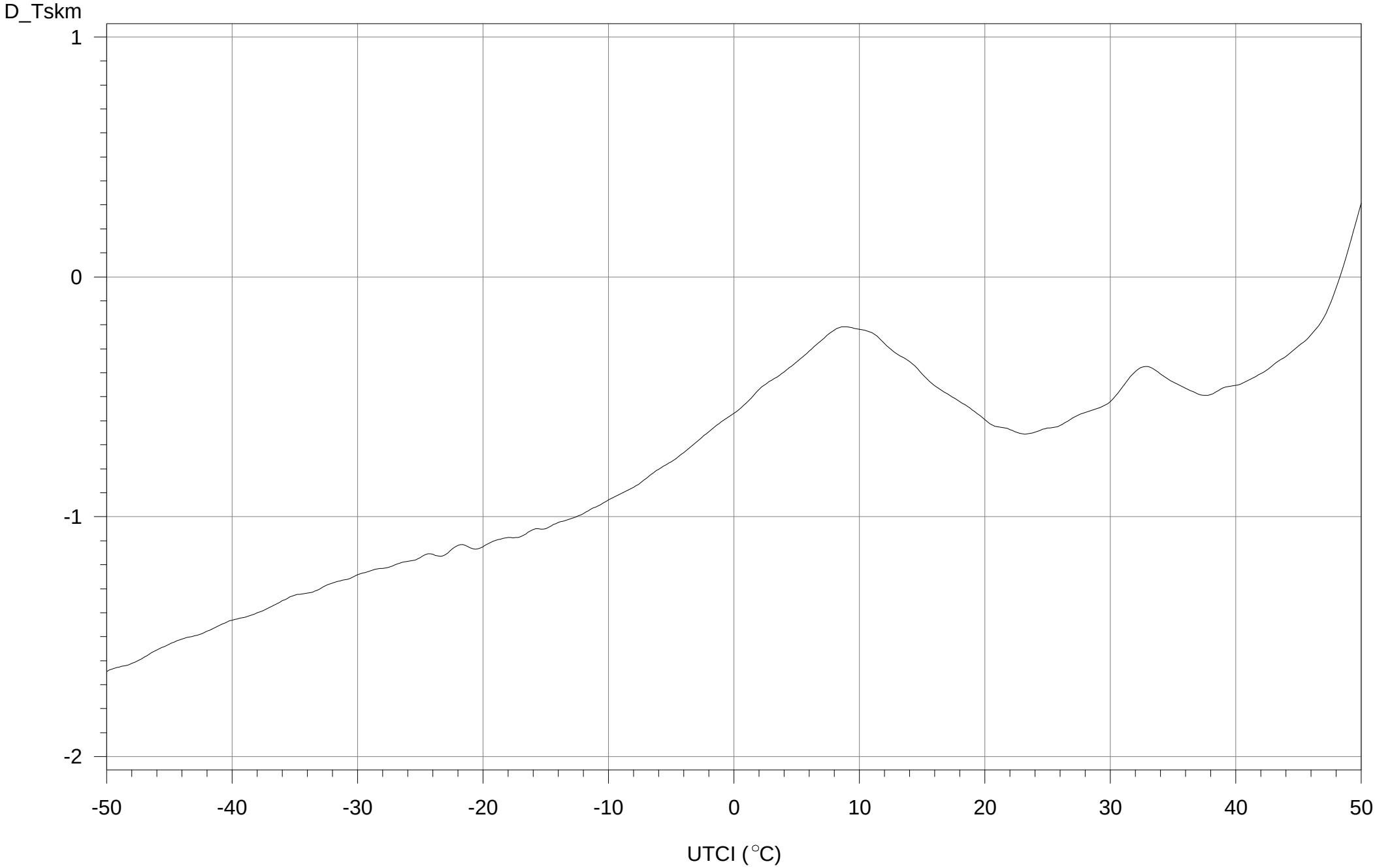
(for reference conditions)



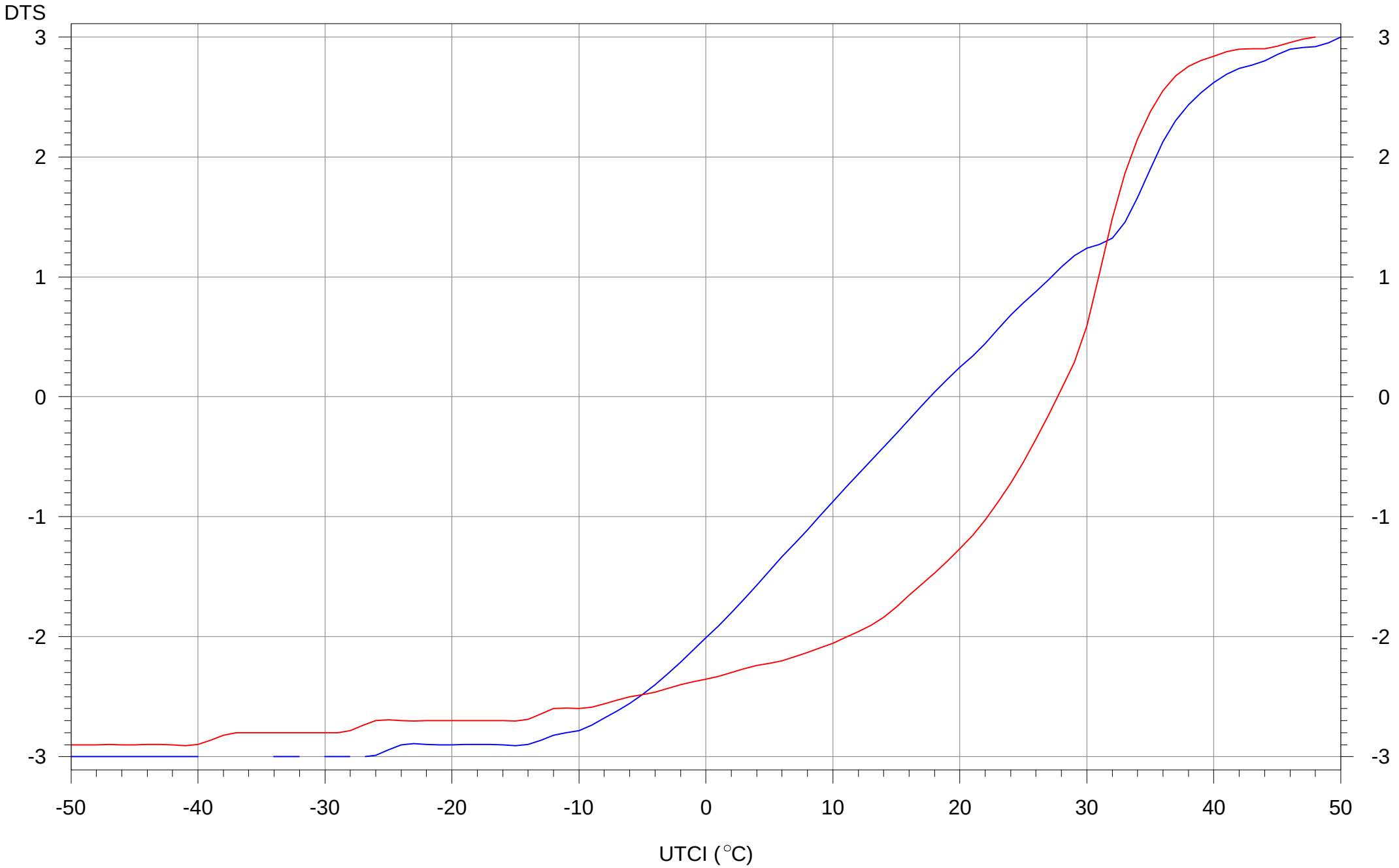
averaged over responses after 30, 60, 90 and 120 min
(for reference conditions)



Time gradient of rectal temperature Tre_120 - Tre_60 (K/h)
(for reference conditions)

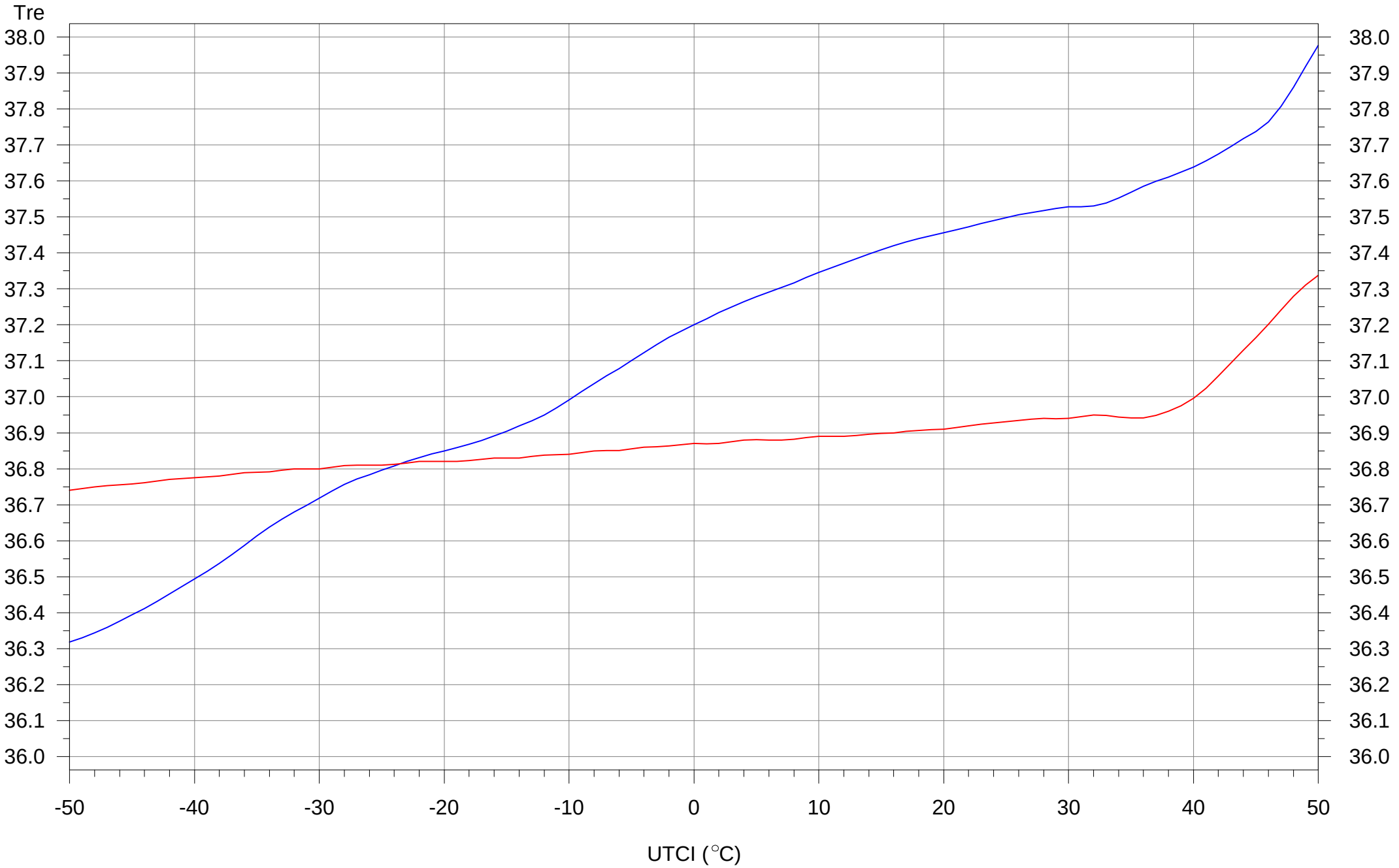


Time gradient of mean skin temperature Tskm_120 - Tskm_60 (K/h)
(for reference conditions)



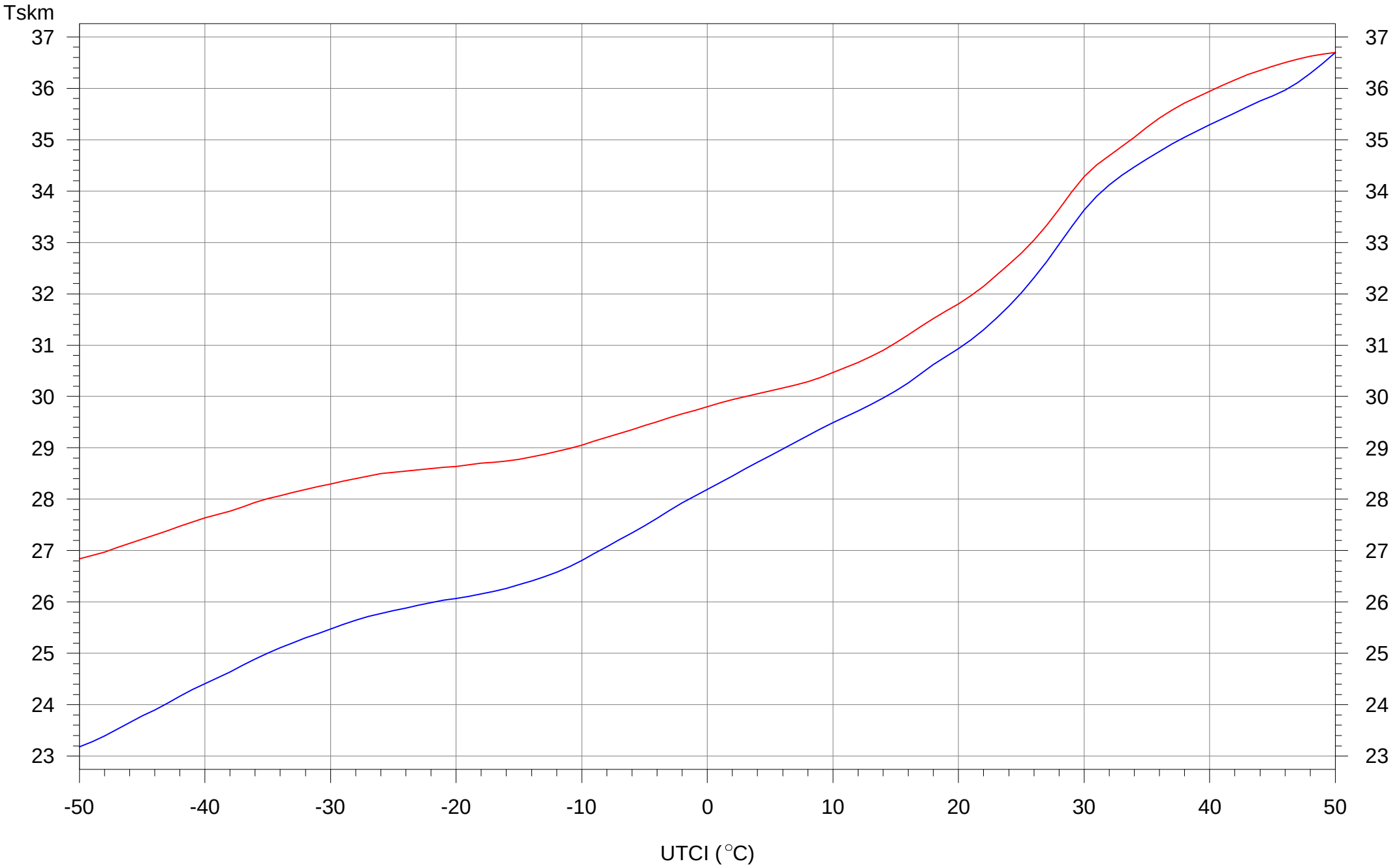
Dynamic Thermal Sensation (DTS) for the reference conditions

30 min 120 min

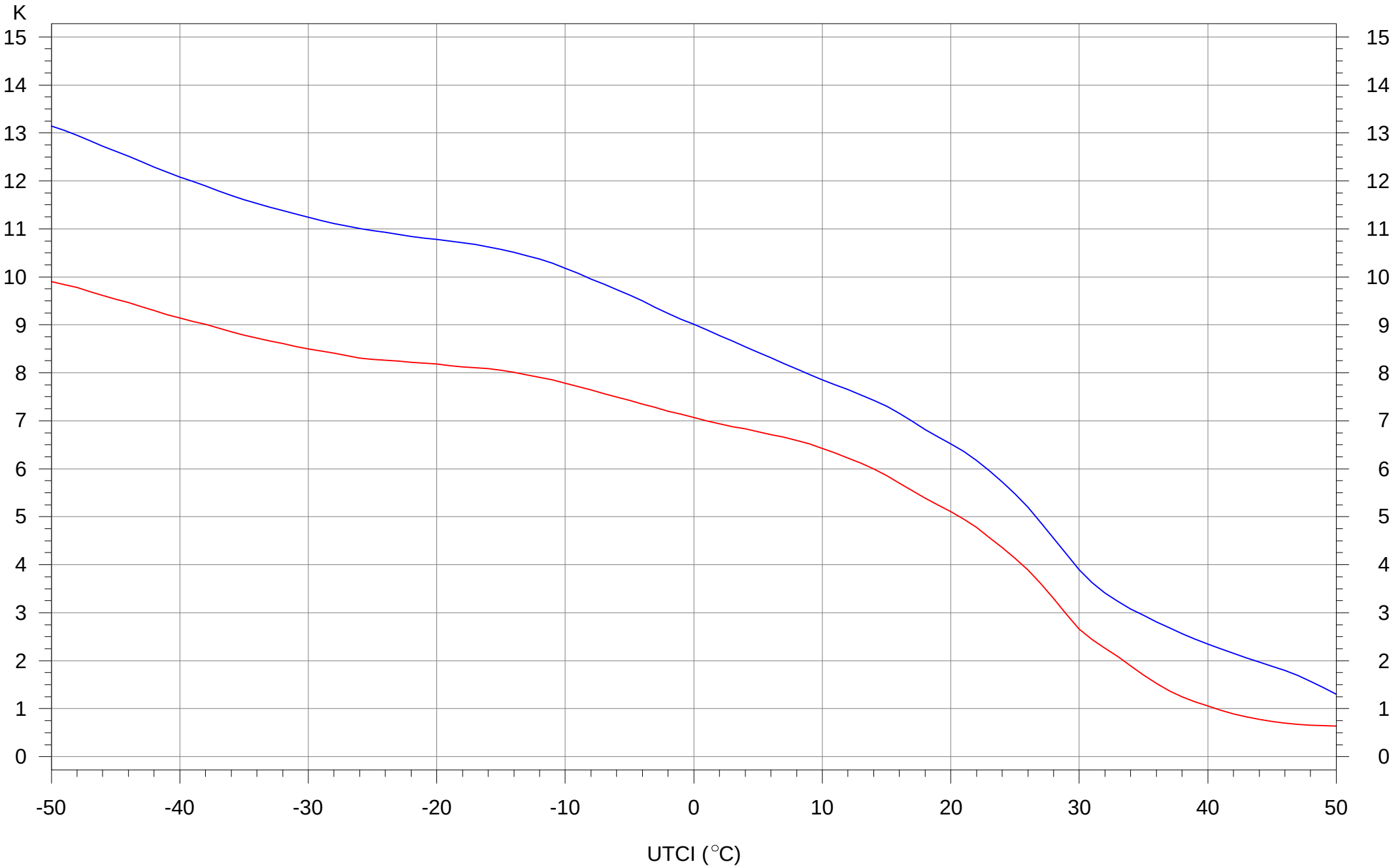


Rectal temperature (degC) for the reference conditions

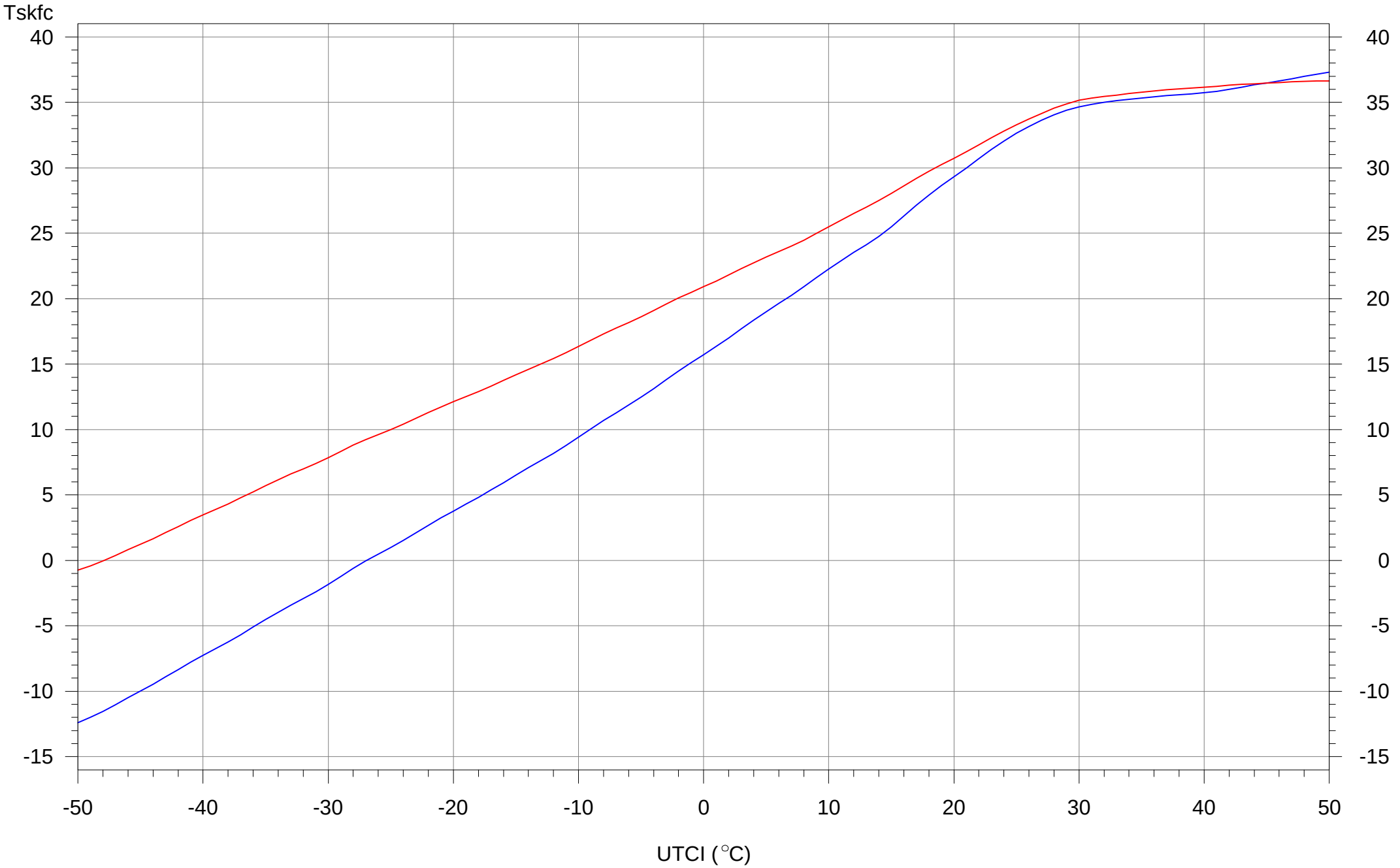
30 min 120 min



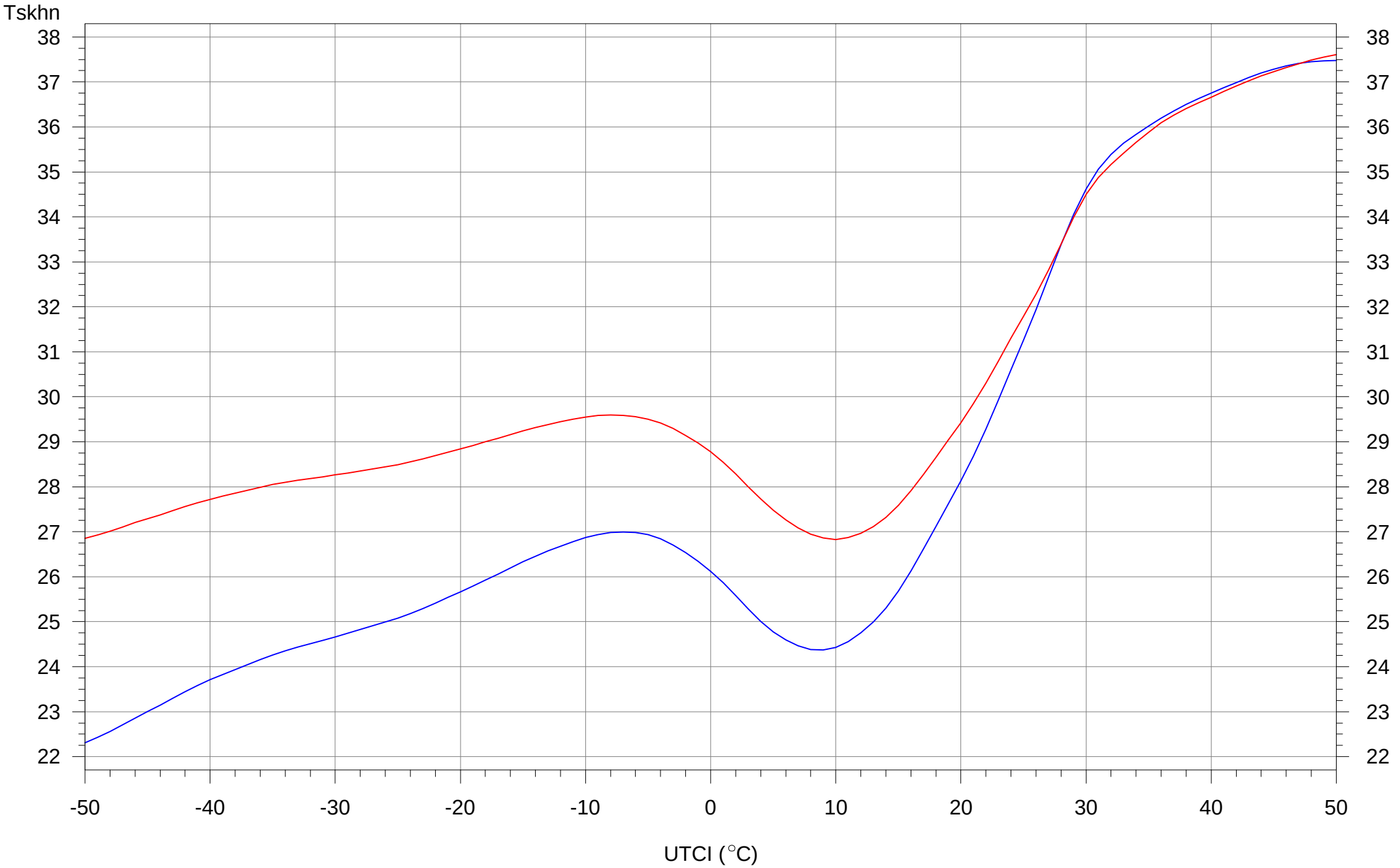
Mean skin temperature (degC) for the reference conditions
30 min 120 min



Tre-Tskm (degC) for the reference conditions
30 min 120 min

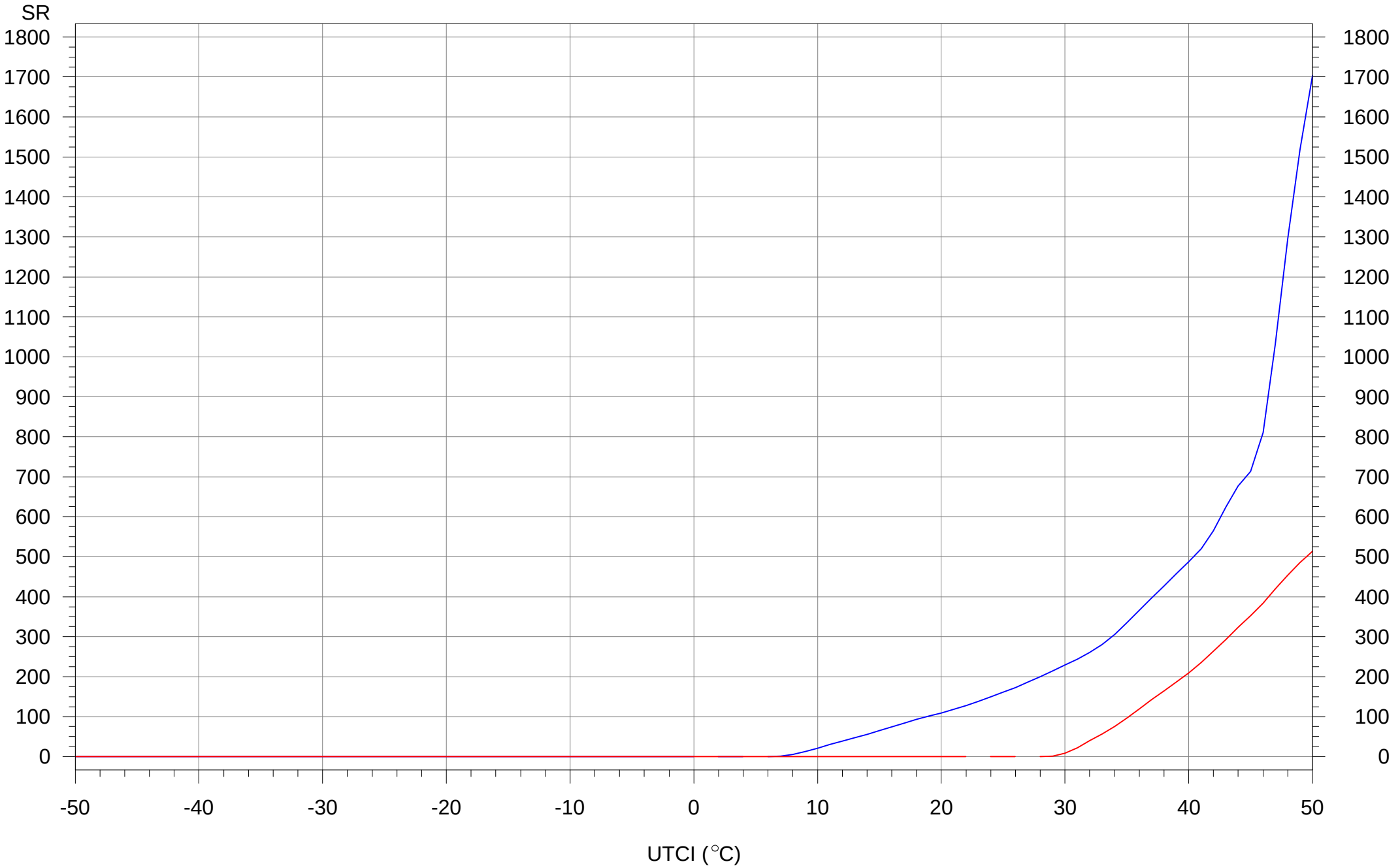


Face skin temperature (degC) for the reference conditions
30 min 120 min



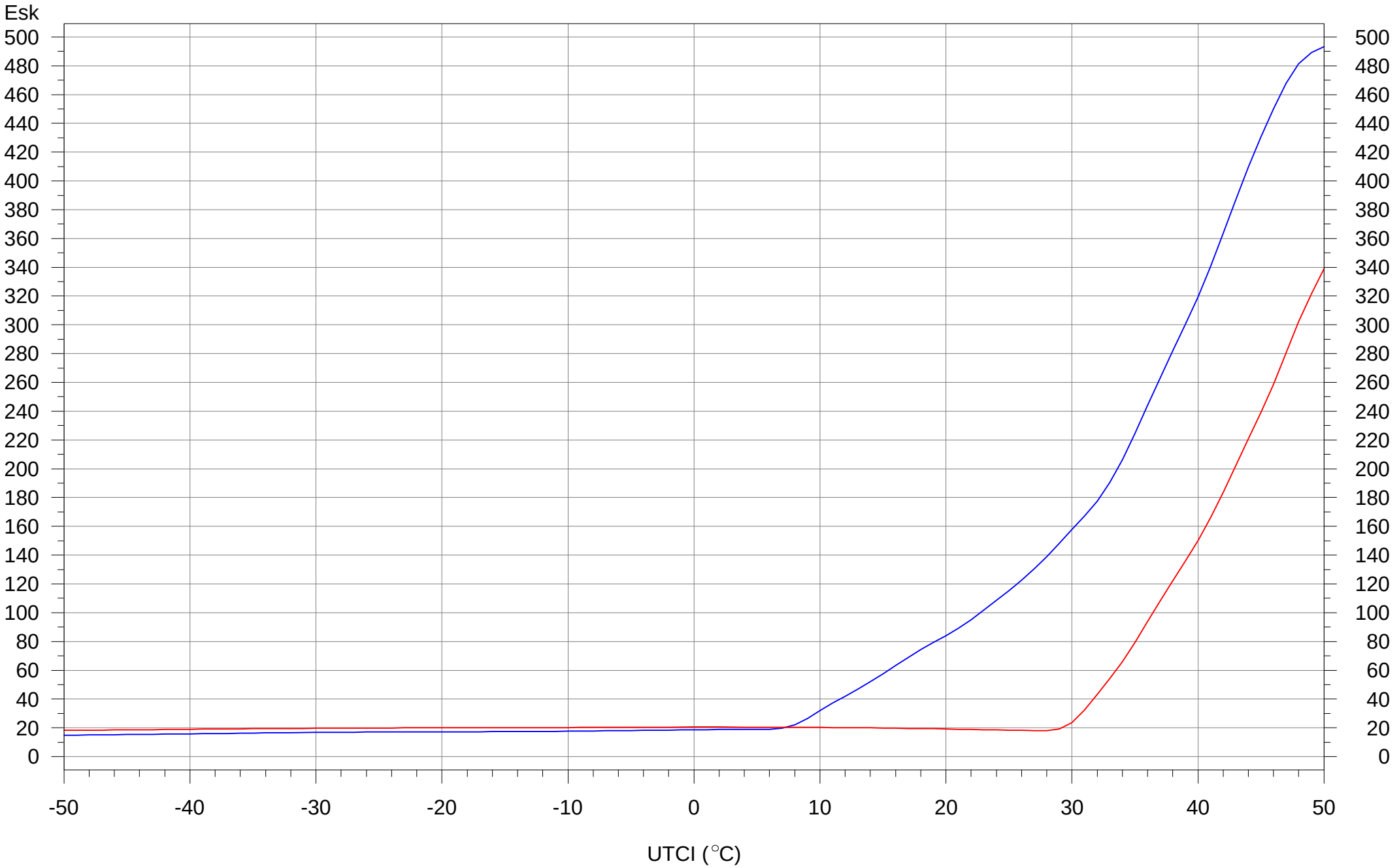
Hand skin temperature (degC) for the reference conditions

30 min 120 min



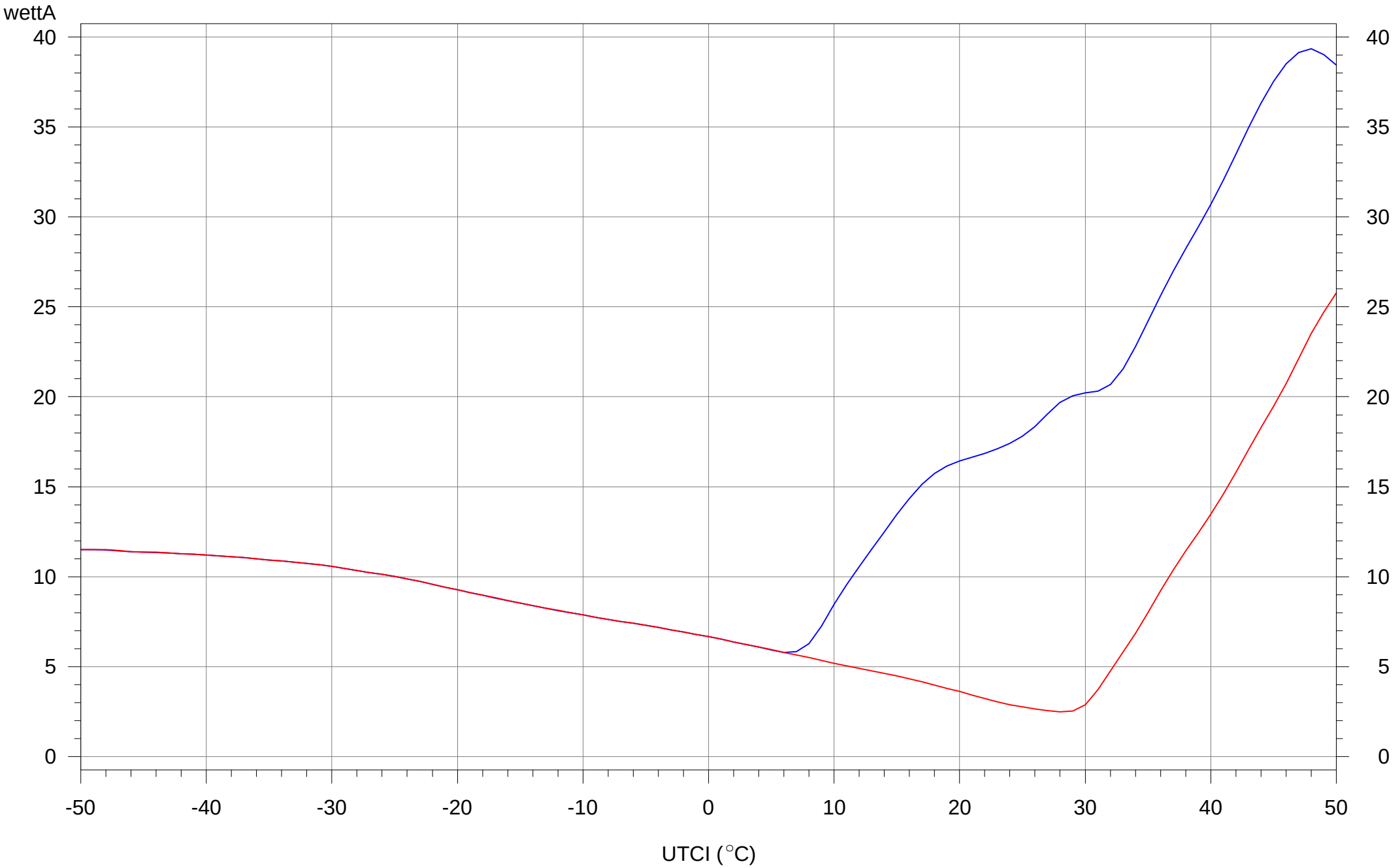
Sweat rate (g/h) for the reference conditions

30 min 120 min

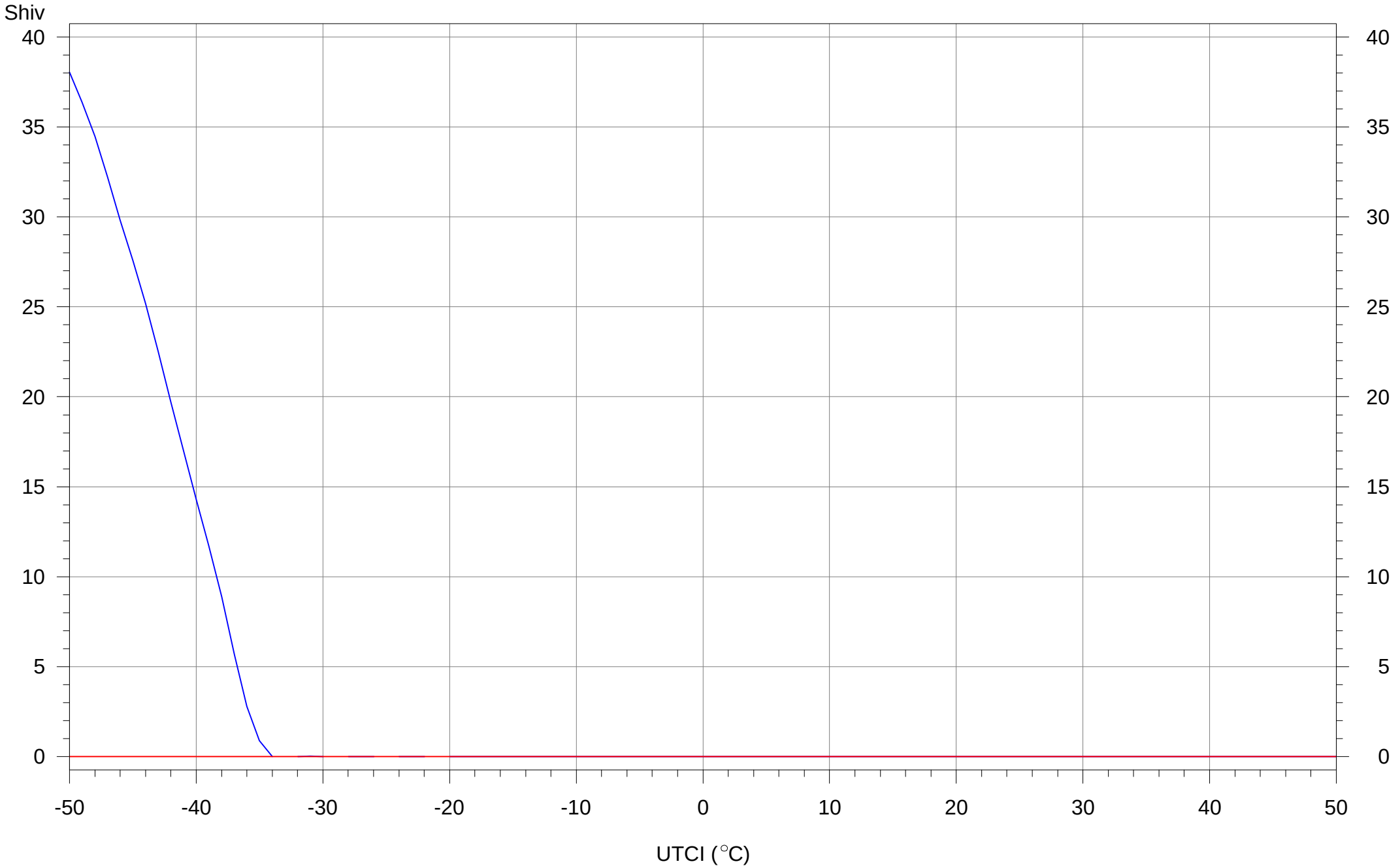


Latent heat loss (W) for the reference conditions

30 min 120 min

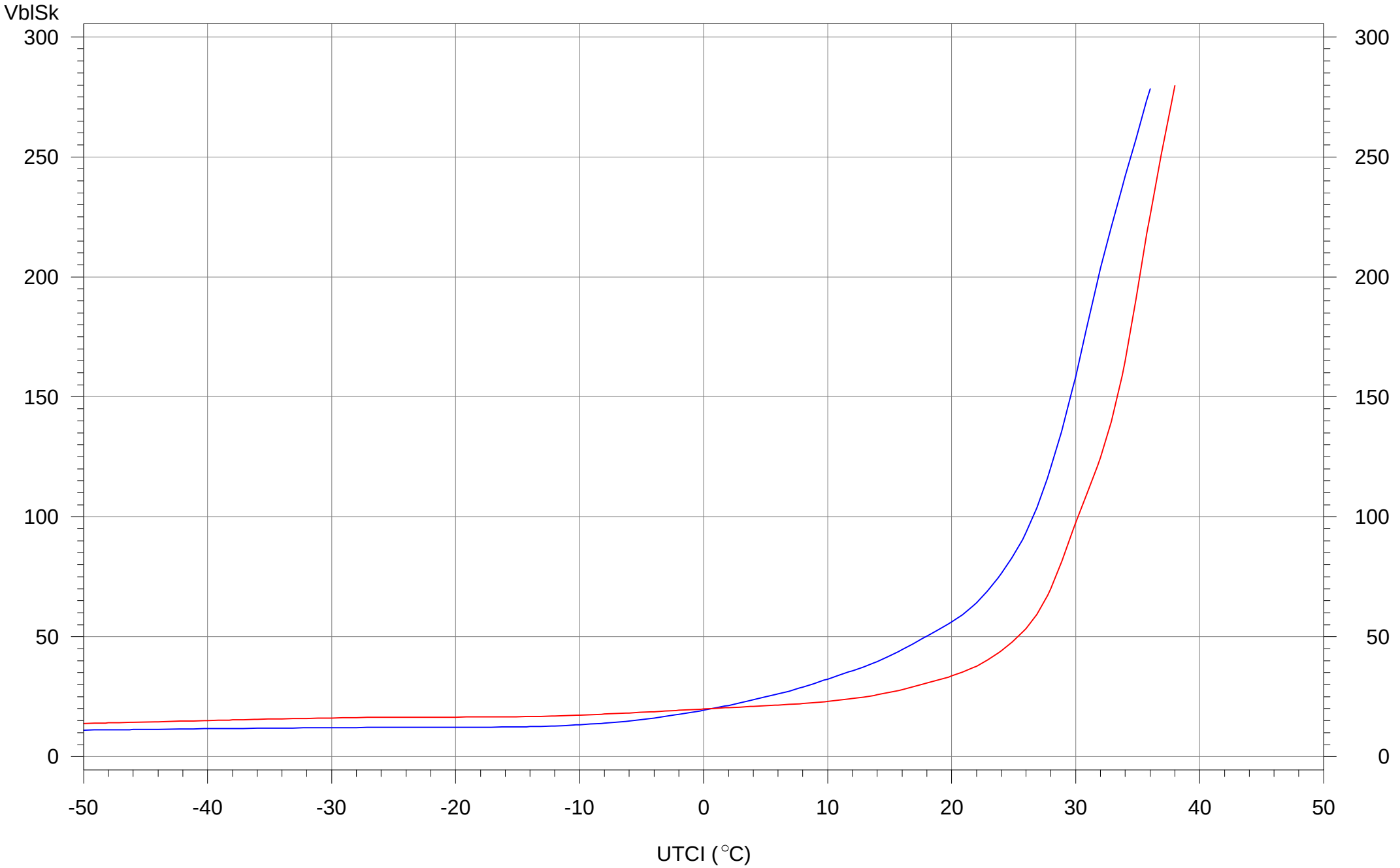


Skin wettedness (%) for the reference conditions
30 min 120 min



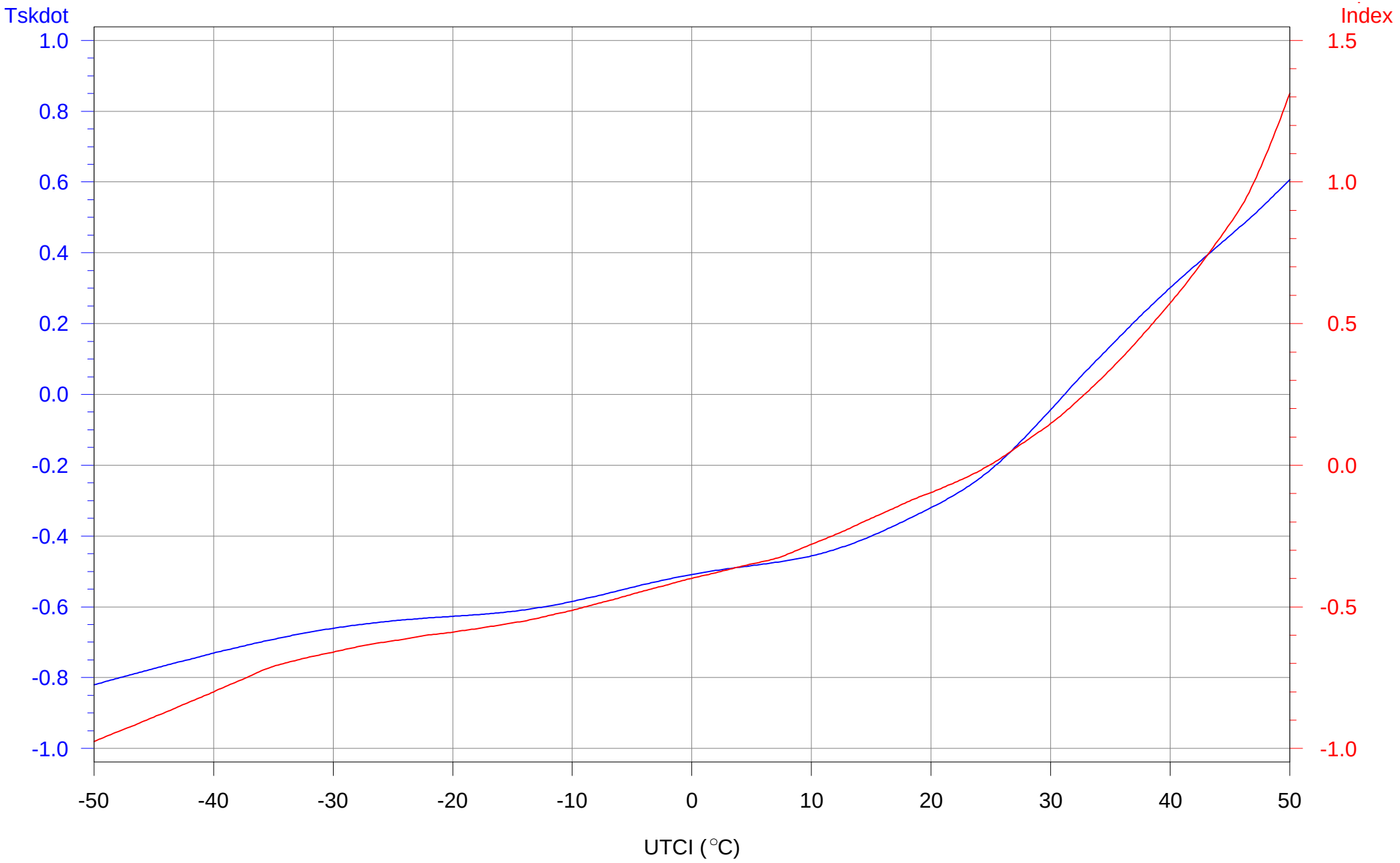
Shivering (W) for the reference conditions

30 min 120 min



Skin blood flow (% of basal value) for the reference conditions

30 min 120 min



Immediate step change in skin temperature after entering the climate (Tskdot, K/min)
Response Index value (nd)
plotted for the reference conditions

Bröde P, Fiala D, Błażejczyk K, Holmér I, Jendritzky G, Kampmann B, Tinz B, Havenith G
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ESM 2 Criteria used for categorizing values of UTCI in terms of thermal stress

UTCI (°C)	Criterion derived from UTCI-Fiala model response	Stress Category	UTCI range (°C)
48	Increase in rectal temperature time gradient	extreme heat stress	above +46
48	steep decrease in total net heat loss		
46	averaged sweat rate >650 g/h, steep increase		
40	core to skin temperature gradient < 1K (at 30 min)	very strong heat stress	+38 to +46
38	increase in rectal temperature at 30 min		
36	Dynamic Thermal Sensation 120 min > +2	strong heat stress	+32 to +38
33	Averaged sweat rate > 200 g/h		
33	increase in rectal temperature at 120 min		
32	latent heat loss >40 W at 30 min		
32	instantaneous change in skin temperature > 0 K/min		
30	change of slope (vs. UTCI) in Tskm, Tskfc, Tskhn, sweat rate, Tre	moderate heat stress	+26 to +32
30	occurrence of sweating at 30 min		
30	steep increase in skin wettedness		
26	Averaged sweat rate > 100 g/h		
26	Dynamic Thermal Sensation 120 min < 1	(“thermal comfort zone”) no thermal stress	+9 to +26
26	Dynamic Thermal Sensation > 0.5 (averaged value)		
18	Dynamic Thermal Sensation > -0.5 (averaged value)		
18	latent heat loss >40 W averaged over time		
14	Plateau in rectal temperature time gradient	no thermal stress	
13	Dynamic Thermal Sensation > -0.5 at 120 min		
12	latent heat loss >40 W at 120 min		
9	Dynamic Thermal Sensation 120 min < -1	slight cold stress	+9 to 0
9	local minimum of hand skin temperature (put gloves on)		
8	Change in slope of mean skin temperature time gradient		
0	Dynamic Thermal Sensation 120 min < -2	moderate cold stress	0 to -13
0	skin blood flow at 120 min lower than at 30 min (vasoconstriction)		
-2	120 min face skin temperature < 15°C (pain)		
-5	averaged face skin temperature < 15°C (pain)		
-10	Decrease in hand skin temperature		
-10	rectal temperature time gradient < 0 K/h		
-13	30 min face skin temperature < 15°C (pain)		
-13	mean skin temperature time gradient < -1 K/h (for reference)		
-14	120 min face skin temperature < 7°C (numbness)	strong cold stress	-13 to -27
-20	averaged face skin temperature < 7°C (numbness)		
-22	rectal temperature time gradient < -0.1 K/h		
-24	Tre decreases from 30 to 120 min		
-26	increase in core to skin temperature gradient		
-27	120 min face skin temperature < 0°C (frostbite)	very strong cold stress	-27 to -40
-30	steeper decrease in Tre		
-32	30 min face skin temperature < 7°C (numbness)		
-32	Occurrence of Shivering		
-33	rectal temperature time gradient < -0.2 K/h		
-34	averaged face skin temperature < 0°C (frostbite)		
-35	120 min face skin temperature < -5°C (high risk of frostbite)		
-40	rectal temperature time gradient < -0.3 K/h	extreme cold stress	below -40
-48	30 min face skin temperature < 0°C (frostbite)		

ESM 3 Coefficients of a 6th order polynomial regression function approximating the **Offset** (= UTCI – Ta) in °C from input values of air temperature (**Ta**) in °C, of wind speed 10 m above ground level (**va**) in m/s, of water vapour pressure (**pa**) in kPa and of the difference between mean radiant temperature and air temperature (**tm**) in °C. The equation is valid for the input parameters ranging as follows: -50 °C ≤ Ta ≤ +50 °C, va ≤ 30.3 m/s, -30 °C ≤ tm ≤ +70 °C, pa ≤ 5 kPa (relative humidity ≤ 100%)

Polynomial regression equation for **Offset** = UTCI – Ta (°C)

Ta: air temperature (°C) **tm**: ΔTmrt=Tr-Ta (°C)
va: wind speed in 10 m height (m/s) **pa**: water vapour pressure (kPa)

polynomial term	*coefficient*	*polynomial term*	*coefficient*
constant term	6.07562052E-01	tm*pa	-3.69476348E-02
Ta	-2.27712343E-02	Ta*tm*pa	1.62325322E-03
Ta*Ta	8.06470249E-04	Ta*Ta*tm*pa	-3.14279680E-05
Ta*Ta*Ta	-1.54271372E-04	Ta*Ta*Ta*tm*pa	2.59835559E-06
Ta*Ta*Ta*Ta	-3.24651735E-06	Ta*Ta*Ta*Ta*tm*pa	-4.77136523E-08
Ta*Ta*Ta*Ta*Ta	7.32602852E-08	va*tm*pa	8.64203390E-03
Ta*Ta*Ta*Ta*Ta*Ta	1.35959073E-09	Ta*va*tm*pa	-6.87405181E-04
va	-2.25836520E+00	Ta*Ta*va*tm*pa	-9.13863872E-06
Ta*va	8.80326035E-02	Ta*Ta*Ta*va*tm*pa	5.15916806E-07
Ta*Ta*va	2.16844454E-03	va*va*tm*pa	-3.59217476E-05
Ta*Ta*Ta*va	-1.53347087E-05	Ta*va*va*tm*pa	3.28696511E-05
Ta*Ta*Ta*Ta*va	-5.72983704E-07	Ta*Ta*va*va*tm*pa	-7.10542454E-07
Ta*Ta*Ta*Ta*Ta*va	-2.55090145E-09	va*va*va*tm*pa	-1.24382300E-05
va*va	-7.51269505E-01	Ta*va*va*va*tm*pa	-7.38584400E-09
Ta*va*va	-4.08350271E-03	va*va*va*va*tm*pa	2.20609296E-07
Ta*Ta*va*va	-5.21670675E-05	tm*tm*pa	-7.32469180E-04
Ta*Ta*Ta*va*va	1.94544667E-06	Ta*tm*tm*pa	-1.87381964E-05
Ta*Ta*Ta*Ta*va*va	1.14099531E-08	Ta*Ta*tm*tm*pa	4.80925239E-06
va*va*va	1.58137256E-01	Ta*Ta*Ta*tm*tm*pa	-8.75492040E-08
Ta*va*va*va	-6.57263143E-05	va*tm*tm*pa	2.77862930E-05
Ta*Ta*va*va*va	2.22697524E-07	Ta*va*tm*tm*pa	-5.06004592E-06
Ta*Ta*Ta*va*va*va	-4.16117031E-08	Ta*Ta*va*tm*tm*pa	1.14325367E-07
va*va*va*va	-1.27762753E-02	va*va*tm*tm*pa	2.53016723E-06
Ta*va*va*va*va	9.66891875E-06	Ta*va*va*tm*tm*pa	-1.72857035E-08
Ta*Ta*va*va*va*va	2.52785852E-09	va*va*va*tm*tm*pa	-3.95079398E-08
va*va*va*va*va	4.56306672E-04	tm*tm*tm*pa	-3.59413173E-07
Ta*va*va*va*va*va	-1.74202546E-07	Ta*tm*tm*tm*pa	7.04388046E-07
va*va*va*va*va*va	-5.91491269E-06	Ta*Ta*tm*tm*tm*pa	-1.89309167E-08
tm	3.98374029E-01	va*tm*tm*tm*pa	-4.79768731E-07
Ta*tm	1.83945314E-04	Ta*va*tm*tm*tm*pa	7.96079978E-09
Ta*Ta*tm	-1.73754510E-04	va*va*tm*tm*tm*pa	1.62897058E-09
Ta*Ta*Ta*tm	-7.60781159E-07	tm*tm*tm*tm*pa	3.94367674E-08
Ta*Ta*Ta*Ta*tm	3.77830287E-08	Ta*tm*tm*tm*tm*pa	-1.18566247E-09
Ta*Ta*Ta*Ta*Ta*tm	5.43079673E-10	va*tm*tm*tm*tm*pa	3.34678041E-10
va*tm	-2.00518269E-02	tm*tm*tm*tm*tm*pa	-1.15606447E-10
Ta*va*tm	8.92859837E-04	pa*pa	-2.80626406E+00
Ta*Ta*va*tm	3.45433048E-06	Ta*pa*pa	5.48712484E-01
Ta*Ta*Ta*va*tm	-3.77925774E-07	Ta*Ta*pa*pa	-3.99428410E-03
Ta*Ta*Ta*Ta*va*tm	-1.69699377E-09	Ta*Ta*Ta*pa*pa	-9.54009191E-04
va*va*tm	1.69992415E-04	Ta*Ta*Ta*Ta*pa*pa	1.93090978E-05
Ta*va*va*tm	-4.99204314E-05	va*pa*pa	-3.08806365E-01
Ta*Ta*va*va*tm	2.47417178E-07	Ta*va*pa*pa	1.16952364E-02
Ta*Ta*Ta*va*va*tm	1.07596466E-08	Ta*Ta*va*pa*pa	4.95271903E-04
va*va*va*tm	8.49242932E-05	Ta*Ta*Ta*va*pa*pa	-1.90710882E-05
Ta*va*va*va*tm	1.35191328E-06	va*va*pa*pa	2.10787756E-03
Ta*Ta*va*va*va*tm	-6.21531254E-09	Ta*va*va*pa*pa	-6.98445738E-04
va*va*va*va*tm	-4.99410301E-06	Ta*Ta*va*va*pa*pa	2.30109073E-05
Ta*va*va*va*va*tm	-1.89489258E-08	va*va*va*pa*pa	4.17856590E-04
va*va*va*va*va*tm	8.15300114E-08	Ta*va*va*va*pa*pa	-1.27043871E-05
tm*tm	7.55043090E-04	va*va*va*va*pa*pa	-3.04620472E-06

Polynomial regression equation for **Offset** = UTCI – Ta (°C)

Ta: air temperature (°C) **tm**: ΔTmrt=Tr-Ta (°C)
va: wind speed in 10 m height (m/s) **pa**: water vapour pressure (kPa)

polynomial term	*coefficient*	*polynomial term*	*coefficient*
Ta*tm*tm	-5.65095215E-05	tm*pa*pa	5.14507424E-02
Ta*Ta*tm*tm	-4.52166564E-07	Ta*tm*pa*pa	-4.32510997E-03
Ta*Ta*Ta*tm*tm	2.46688878E-08	Ta*Ta*tm*pa*pa	8.99281156E-05
Ta*Ta*Ta*Ta*tm*tm	2.42674348E-10	Ta*Ta*Ta*tm*pa*pa	-7.14663943E-07
va*tm*tm	1.54547250E-04	va*tm*pa*pa	-2.66016305E-04
Ta*va*tm*tm	5.24110970E-06	Ta*va*tm*pa*pa	2.63789586E-04
Ta*Ta*va*tm*tm	-8.75874982E-08	Ta*Ta*va*tm*pa*pa	-7.01199003E-06
Ta*Ta*Ta*va*tm*tm	-1.50743064E-09	va*va*tm*pa*pa	-1.06823306E-04
va*va*tm*tm	-1.56236307E-05	Ta*va*va*tm*pa*pa	3.61341136E-06
Ta*va*va*tm*tm	-1.33895614E-07	va*va*va*tm*pa*pa	2.29748967E-07
Ta*Ta*va*va*tm*tm	2.49709824E-09	tm*tm*pa*pa	3.04788893E-04
va*va*va*tm*tm	6.51711721E-07	Ta*tm*tm*pa*pa	-6.42070836E-05
Ta*va*va*va*tm*tm	1.94960053E-09	Ta*Ta*tm*tm*pa*pa	1.16257971E-06
va*va*va*va*tm*tm	-1.00361113E-08	va*tm*tm*pa*pa	7.68023384E-06
tm*tm*tm	-1.21206673E-05	Ta*va*tm*tm*pa*pa	-5.47446896E-07
Ta*tm*tm*tm	-2.18203660E-07	va*va*tm*tm*pa*pa	-3.59937910E-08
Ta*Ta*tm*tm*tm	7.51269482E-09	tm*tm*tm*pa*pa	-4.36497725E-06
Ta*Ta*Ta*tm*tm*tm	9.79063848E-11	Ta*tm*tm*tm*pa*pa	1.68737969E-07
va*tm*tm*tm	1.25006734E-06	va*tm*tm*tm*pa*pa	2.67489271E-08
Ta*va*tm*tm*tm	-1.81584736E-09	tm*tm*tm*tm*pa*pa	3.23926897E-09
Ta*Ta*va*tm*tm*tm	-3.52197671E-10	pa*pa*pa	-3.53874123E-02
va*va*tm*tm*tm	-3.36514630E-08	Ta*pa*pa*pa	-2.21201190E-01
Ta*va*va*tm*tm*tm	1.35908359E-10	Ta*Ta*pa*pa*pa	1.55126038E-02
va*va*va*tm*tm*tm	4.17032620E-10	Ta*Ta*Ta*pa*pa*pa	-2.63917279E-04
tm*tm*tm*tm	-1.30369025E-09	va*pa*pa*pa	4.53433455E-02
Ta*tm*tm*tm*tm	4.13908461E-10	Ta*va*pa*pa*pa	-4.32943862E-03
Ta*Ta*tm*tm*tm*tm	9.22652254E-12	Ta*Ta*va*pa*pa*pa	1.45389826E-04
va*tm*tm*tm*tm	-5.08220384E-09	va*va*pa*pa*pa	2.17508610E-04
Ta*va*tm*tm*tm*tm	-2.24730961E-11	Ta*va*va*pa*pa*pa	-6.66724702E-05
va*va*tm*tm*tm*tm	1.17139133E-10	va*va*va*pa*pa*pa	3.33217140E-05
tm*tm*tm*tm*tm	6.62154879E-10	tm*pa*pa*pa	-2.26921615E-03
Ta*tm*tm*tm*tm*tm	4.03863260E-13	Ta*tm*pa*pa*pa	3.80261982E-04
va*tm*tm*tm*tm*tm	1.95087203E-12	Ta*Ta*tm*pa*pa*pa	-5.45314314E-09
tm*tm*tm*tm*tm*tm	-4.73602469E-12	va*tm*pa*pa*pa	-7.96355448E-04
pa	5.12733497E+00	Ta*va*tm*pa*pa*pa	2.53458034E-05
Ta*pa	-3.12788561E-01	va*va*tm*pa*pa*pa	-6.31223658E-06
Ta*Ta*pa	-1.96701861E-02	tm*tm*pa*pa*pa	3.02122035E-04
Ta*Ta*Ta*pa	9.99690870E-04	Ta*tm*tm*pa*pa*pa	-4.77403547E-06
Ta*Ta*Ta*Ta*pa	9.51738512E-06	va*tm*tm*pa*pa*pa	1.73825715E-06
Ta*Ta*Ta*Ta*Ta*pa	-4.66426341E-07	tm*tm*tm*pa*pa*pa	-4.09087898E-07
va*pa	5.48050612E-01	pa*pa*pa*pa	6.14155345E-01
Ta*va*pa	-3.30552823E-03	Ta*pa*pa*pa*pa	-6.16755931E-02
Ta*Ta*va*pa	-1.64119440E-03	Ta*Ta*pa*pa*pa*pa	1.33374846E-03
Ta*Ta*Ta*va*pa	-5.16670694E-06	va*pa*pa*pa*pa	3.55375387E-03
Ta*Ta*Ta*Ta*va*pa	9.52692432E-07	Ta*va*pa*pa*pa*pa	-5.13027851E-04
va*va*pa	-4.29223622E-02	va*va*pa*pa*pa*pa	1.02449757E-04
Ta*va*va*pa	5.00845667E-03	tm*pa*pa*pa*pa	-1.48526421E-03
Ta*Ta*va*va*pa	1.00601257E-06	Ta*tm*pa*pa*pa*pa	-4.11469183E-05
Ta*Ta*Ta*va*va*pa	-1.81748644E-06	va*tm*pa*pa*pa*pa	-6.80434415E-06
va*va*va*pa	-1.25813502E-03	tm*tm*pa*pa*pa*pa	-9.77675906E-06
Ta*va*va*va*pa	-1.79330391E-04	pa*pa*pa*pa*pa	8.82773108E-02
Ta*Ta*va*va*va*pa	2.34994441E-06	Ta*pa*pa*pa*pa*pa	-3.01859306E-03
va*va*va*va*pa	1.29735808E-04	va*pa*pa*pa*pa*pa	1.04452989E-03
Ta*va*va*va*va*pa	1.29064870E-06	tm*pa*pa*pa*pa*pa	2.47090539E-04
va*va*va*va*va*pa	-2.28558686E-06	pa*pa*pa*pa*pa*pa	1.48348065E-03

ESM 4: The archive "ESM_4_Table_Offset.ZIP" contains a ReadMe text and a TAB-delimited ASCII-file "ESM_4_Table_Offset.Dat" tabulating values of the **Offset** (= UTCI - Ta) in °C for different input values of:

- Ta: air temperature in°C (range: -50 °C to +50 °C)
- Tr-Ta: difference between mean radiant temperature (Tr) and air temperature in °C (-30 °C to +70 °C)
- va: wind speed in m/s measured 10 m above ground level (0.5 m/s to 30.3 m/s)
- rH: relative humidity in % (5% to 100%)
- pa: water vapour pressure in kPa (0 kPa to 5 kPa)