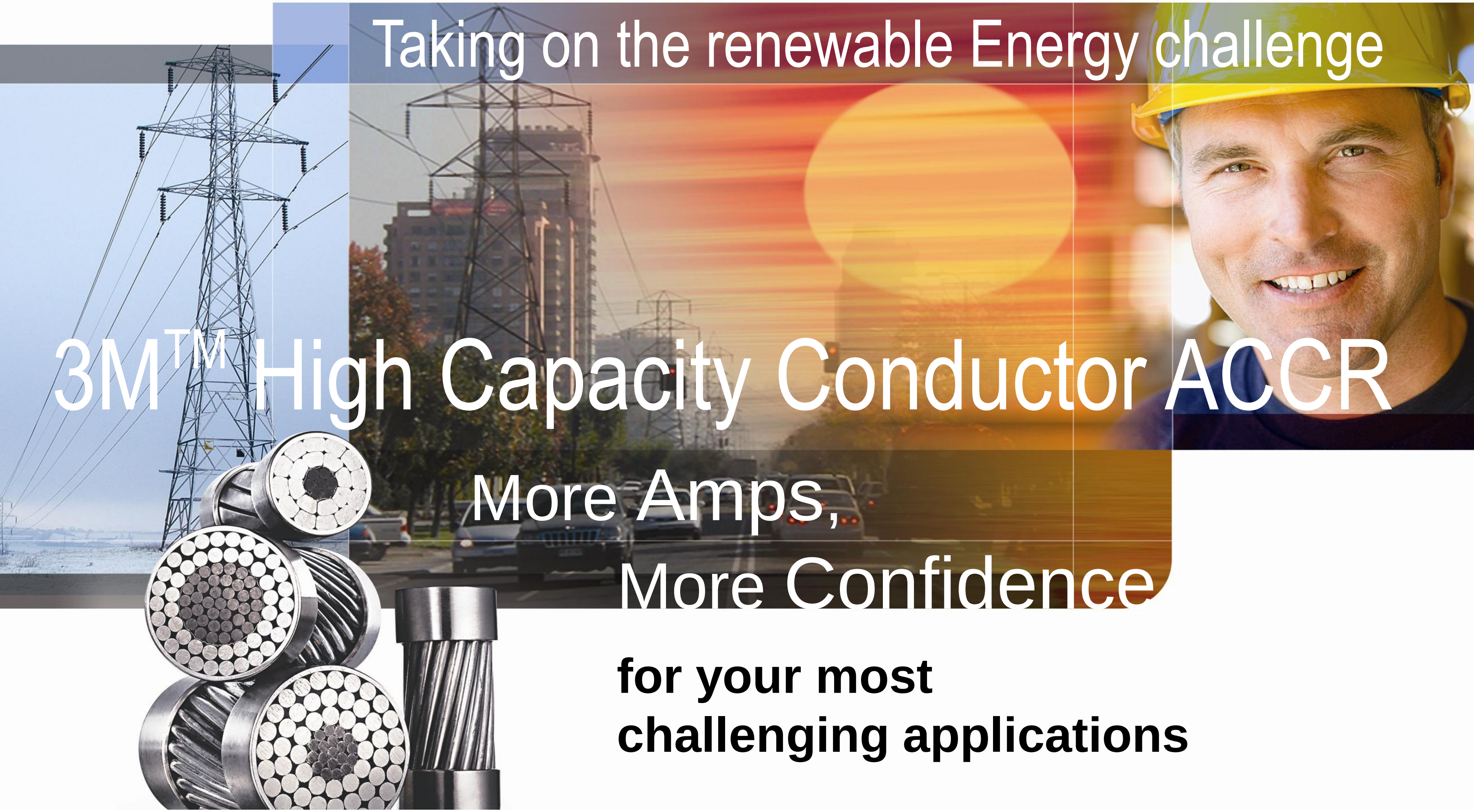

Taking on the renewable Energy challenge

3M™ High Capacity Conductor ACCR

More Amps,
More Confidence

for your most
challenging applications

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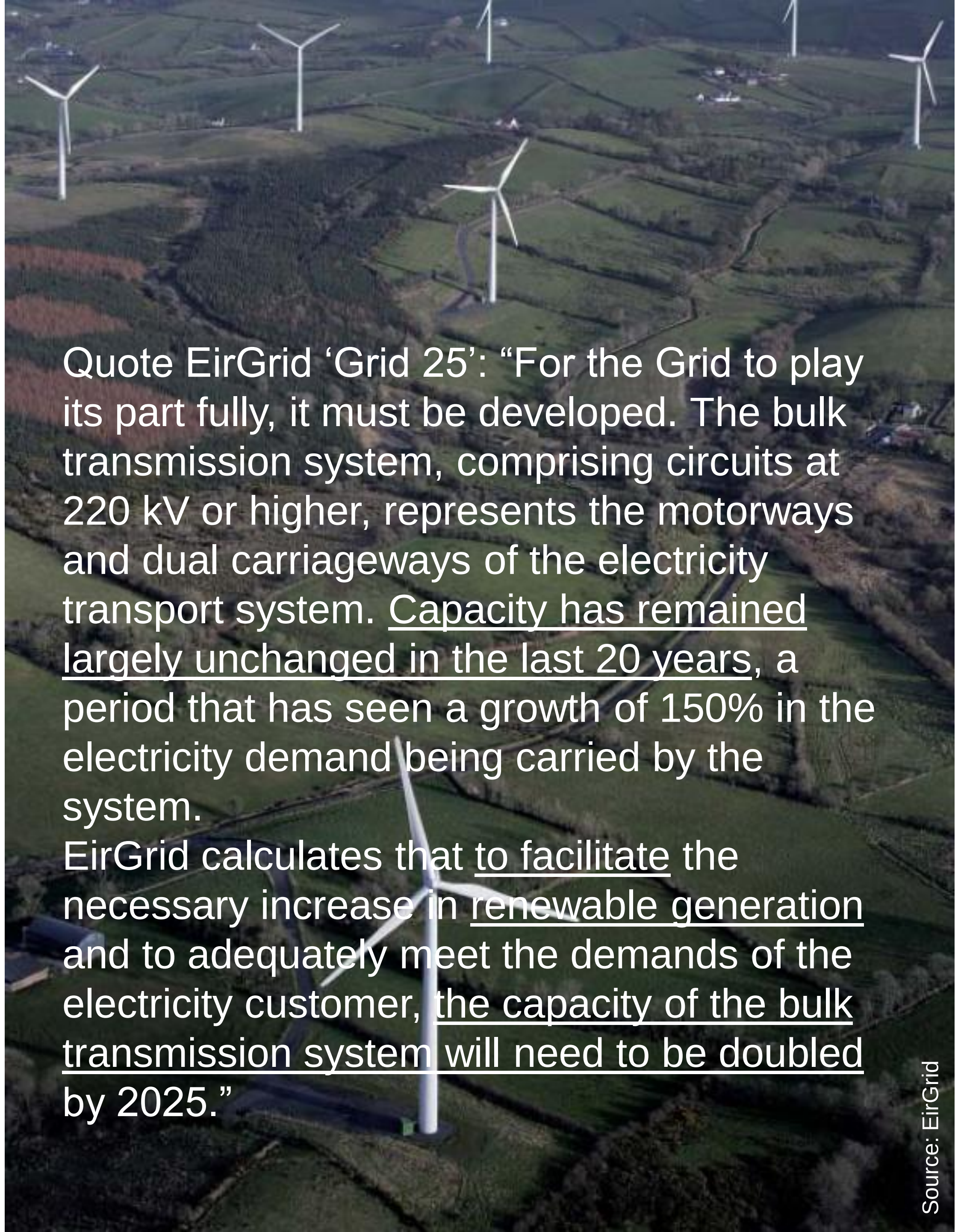
The renewable Energy challenge



Quote EirGrid 'Grid 25': "For the Grid to play its part fully, it must be developed. The bulk transmission system, comprising circuits at 220 kV or higher, represents the motorways and dual carriageways of the electricity transport system. Capacity has remained largely unchanged in the last 20 years, a period that has seen a growth of 150% in the electricity demand being carried by the system.

EirGrid calculates that to facilitate the necessary increase in renewable generation and to adequately meet the demands of the electricity customer, the capacity of the bulk transmission system will need to be doubled by 2025."

Source: EirGrid

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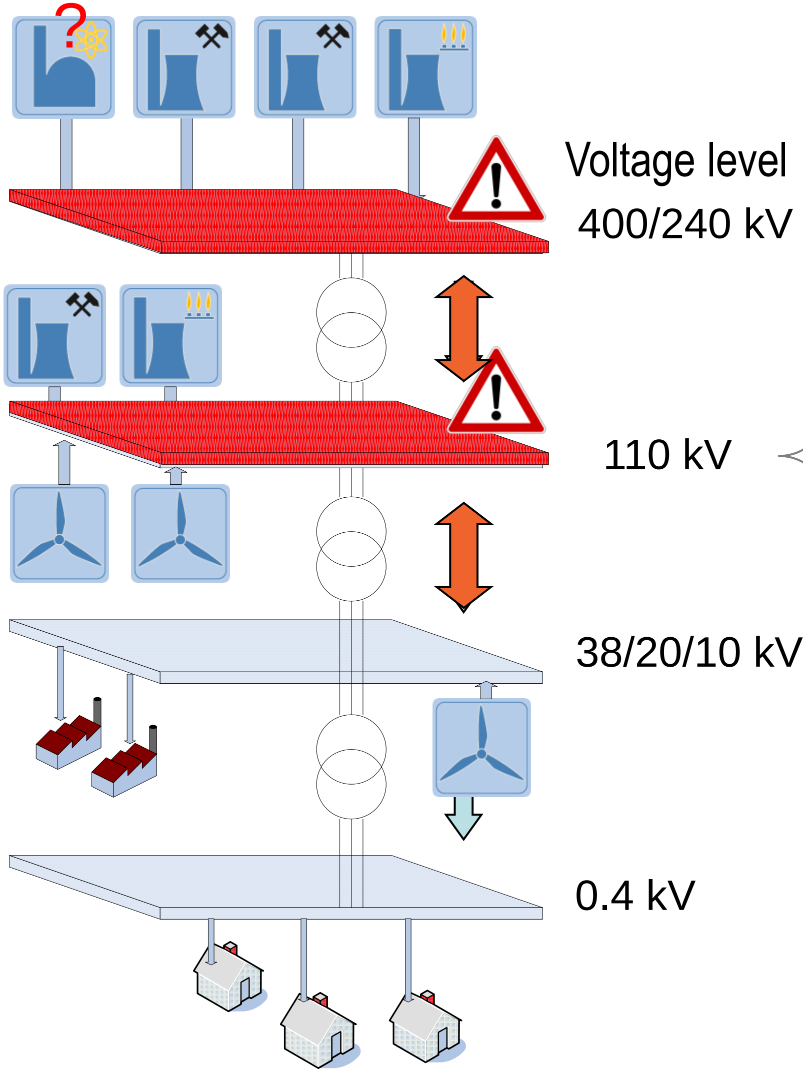
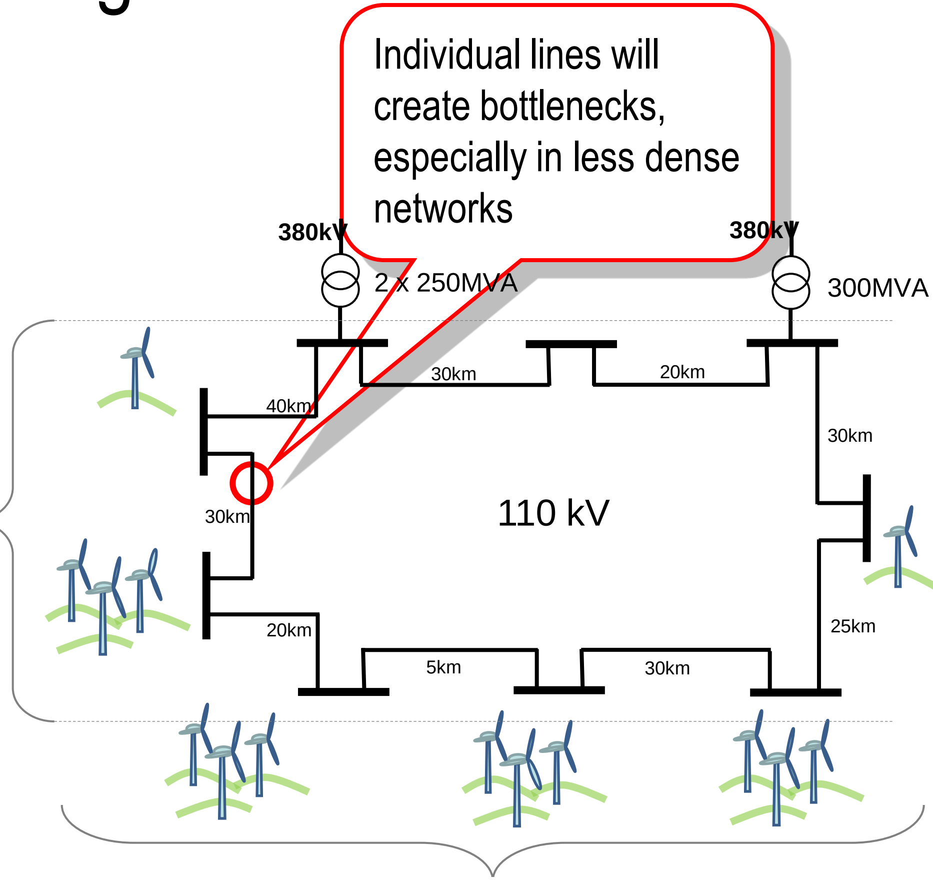
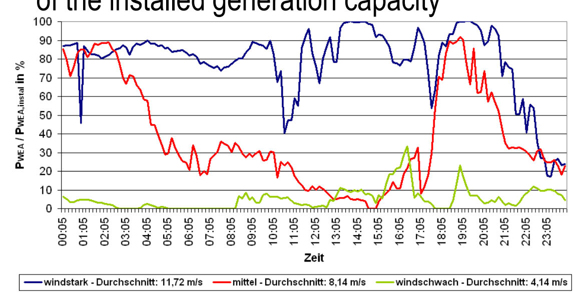
The renewable Energy challenge





Supplied wind energy (24h) as percentage of the installed generation capacity



Visuals: IFHT RWTH Aachen

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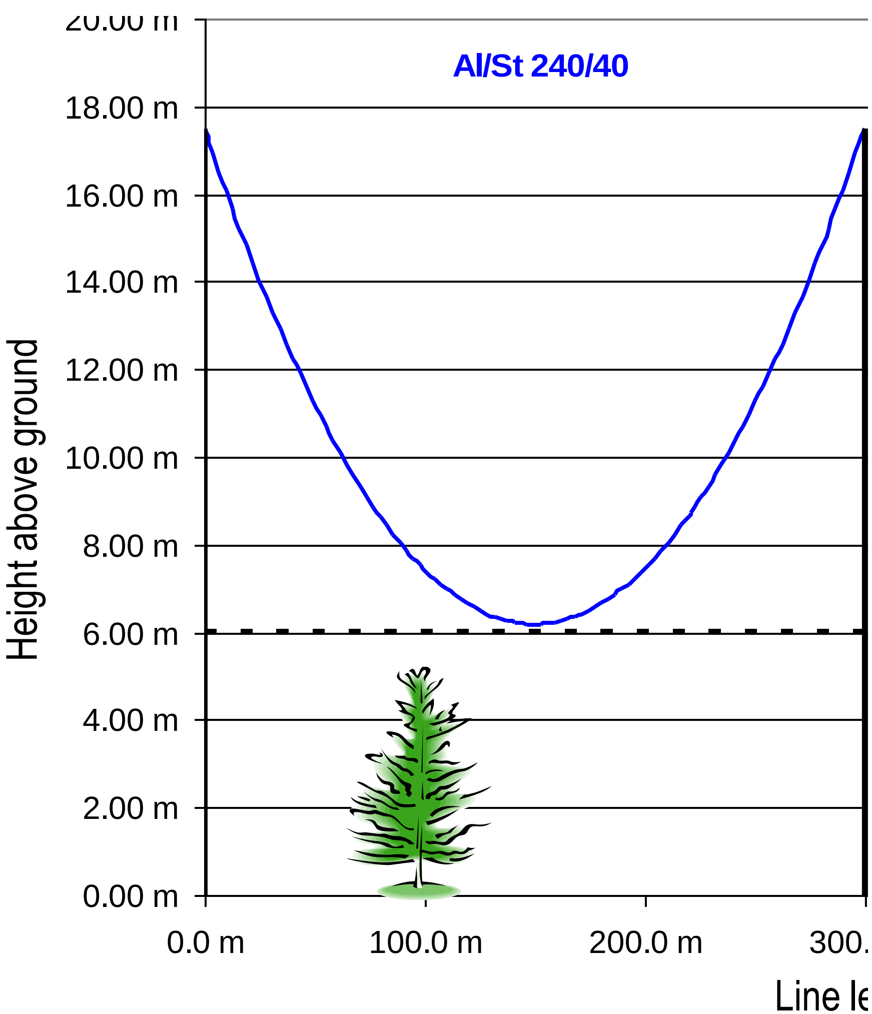
(Design) Criteria for High Capacity Conductors



- **Maximizing ampacity for existing power lines**
  - *Increased revenue*
  - *More useable capacity – improve N-1 ratings on paths*
  - ***More flexibility and responsiveness to serve unexpected load growth, new generation, upgrades on other lines***
  - *Delay the next upgrade*
  - *Maximize the value of your existing grid*
- **Compatible with existing towers & structures**
- Suitable for wider range of environmental conditions
  - *(Heat, Cold, Ice, Wind, Corrosion)*
- **Installation similar to ACSR**
- Good Value
- **Complete Reliability for decades of service**

Ampacity conditions: 35°C ambient, 0.6 m/s wind, 900 W/m² solar, emissivity 0.5, absorptivity 0.5;
Ice load acc. German ice zone 1, tension 18.5 kN per conductor at-5°C plus ice; line designed for 60°C ACSR

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What is 3M™ High Capacity Conductor ACCR?

- A high voltage, overhead transmission conductor…
- …designed as a drop-in replacement for ACSR and ACSS on existing, thermally limited lines ….
- … is installed very similar to ACSR
- …allowing utilities to use existing structures
- …but capable of carrying 2 to 3 times the current.

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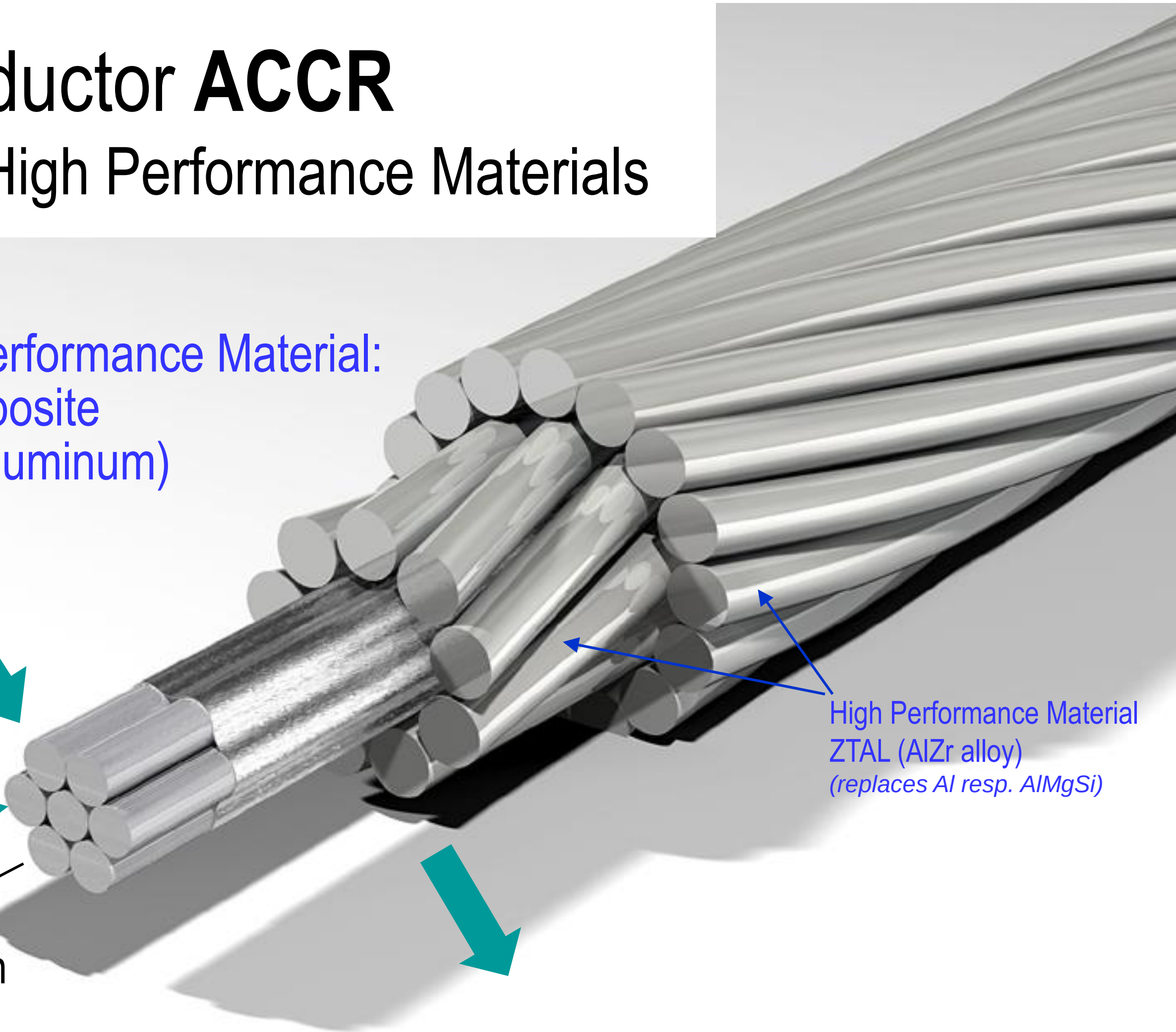
High Capacity Conductor **ACCR**

Trusted Basic Design + High Performance Materials



Innovative High Performance Material:
Metal Matrix Composite
(Ceramic fiber – Aluminum)
(replaces steel)

High Performance Material
ZTAL (AlZr alloy)
(replaces Al resp. AlMgSi)

Compared with steel
- Comparable strength
- Lighter
- Stiffer
- Higher electrical conductivity
- Lower thermal expansion
- Chemically compatible to Aluminum

High Performance

simultaneously achievable:
•Mechanically unload the towers
•Increase clearance to terrain
•Typically double the ampacity
•A highly reliable, proven solution

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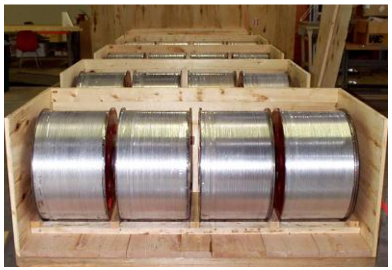
ACCR is result of a multi-year US Dept of Energy Development Program

energy.gov
U.S. DEPARTMENT OF ENERGY

Partners for the development:



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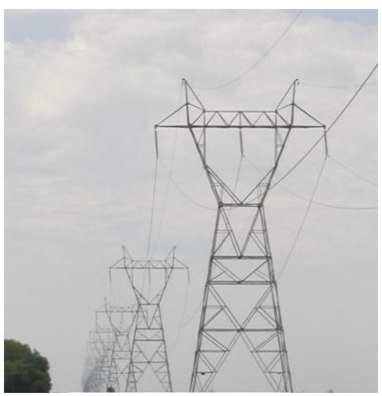
WIRE ROPE

Nexans

PLP
PREFORMED
LINE PRODUCTS



Western
AREA POWER
ADMINISTRATION

UT-BATTELLE

NEETRAC

ACA Conductor Accessories
A division of AFL Telecommunications

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Documented Qualification

…here just the beginning of the list of reports:

Report Number	ACCR Size	Test Subject
Tensile Strength & Stress-Strain Behavior		
1	477	Tensile Strength and Stress-Strain
6	795	Sustained Load Test – Conductor Only
12	1272	Tensile Strength and Stress-Strain
18	477	Rated Breaking Strength
24	596/TW	Tensile Strength, Stress-Strain and Resistance
27	477	Stress-Strain Test #2 - ORNL
28	795	Conductor Strength
31	774	46/37 River Crossing Conductor - Damper Efficiency Test
32	795	Stress-Strain Room Temperature
39	675/TW	ACA Full Tension Splice Tensile Strength
48	795	Tensile Production Lot
58	774-T53	Tensile Strength and Stress-Strain
62	1272	Polynomial Derivation
67	477	Core Mapping
Aeolian Vibration		
4	N/A	WAPA Fargo Field Trial Summary
43	1272	PLP Thermolign® Suspension Assembly
73	477	PLP Thermolign® Dead End Sustained Load
76	477	PLP Thermolign® Suspension Assembly
78	596/TW	PLP Thermolign® Suspension Assembly

For more details see www.3m.com/accr:

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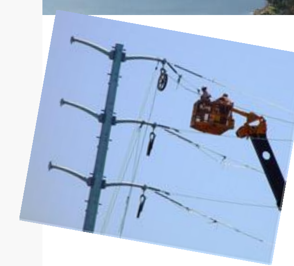
3M ACCR

More Amps, More Confidence

Proven 3M ACCR Performance, References since 2001

3M ACCR Installations		Application	kV	Conductor Size (kcmil)	Conductor Size (mm^2)
TATA Power	Mumbai, India	Load growth Dense population	110	300	150
Xcel Energy	Minneapolis, Minnesota	Installation validation	115	477	238
Hawaiian Electric Company	Oahu, Hawaii	Corrosive environment	46	477	238
Western Area Power Administration	Fargo, North Dakota	Heavy ice and wind loads	230	795	418
Bonneville Power Administration	Washington State	High temperature operation	115	675-TW	322-TW
Western Area Power Administration	Phoenix, Arizona	Installation validation	230	1272	642
Salt River Project	Phoenix, Arizona	High current operation	69	795	418
Pacific Gas & Electric	Santa Clara, California	High temperature operation	115	477	238
San Diego Gas & Electric	San Diego, California	EPRI test	69	795	418
Xcel Energy	Minneapolis, Minnesota	Environmentally sensitive area River crossing	115	795	418
Arizona Public Service	Phoenix, Arizona	Dense population Underbuilds	230	1272	642
Western Area Power Administration	Arizona/California Border	High growth	230	795	418
Shanghai Electric	Shanghai, China	Cost and time savings	115	795	418
Platte River Power Authority	Fort Collins, Colorado	Increased reliability	230	954	490
Aha Macav Power Services	Needles, California	Increased reliability	69	300	150
Allegheny Power	West Virginia	Underbuilt facilities Cost and time savings	138	1033	525
British Columbia Transmission Compa Hydro)	British Columbia	River Crossing	230	788	400
Alabama Power	Birmingham, Alabama	Underbuilt facilities Load growth	230	680	346
Silicon Valley Power	City of Santa Clara, CA	Environmental and aesthetics Reliability	60	715	365
Chongqing	Chongqing, China	Load growth Time savings	220	680	346
Companhia de Transmissao de Energ Eletrica Paulista	Sao Paulo, Brazil	Cost, time and environmental impact savings	138	300	150
Alabama Power	Birmingham, Alabama	Cost and time savings	230	1033	525
CPFL Piratininga	Jundiai, Brasil	Load growth Cost and time savings Social impacts	88	336	171



For most recent information see: http://solutions.3m.com/wps/portal/3M/en_US/EMD_ACCR/ACCR_Home/Proven_Tech/Customer_Install/

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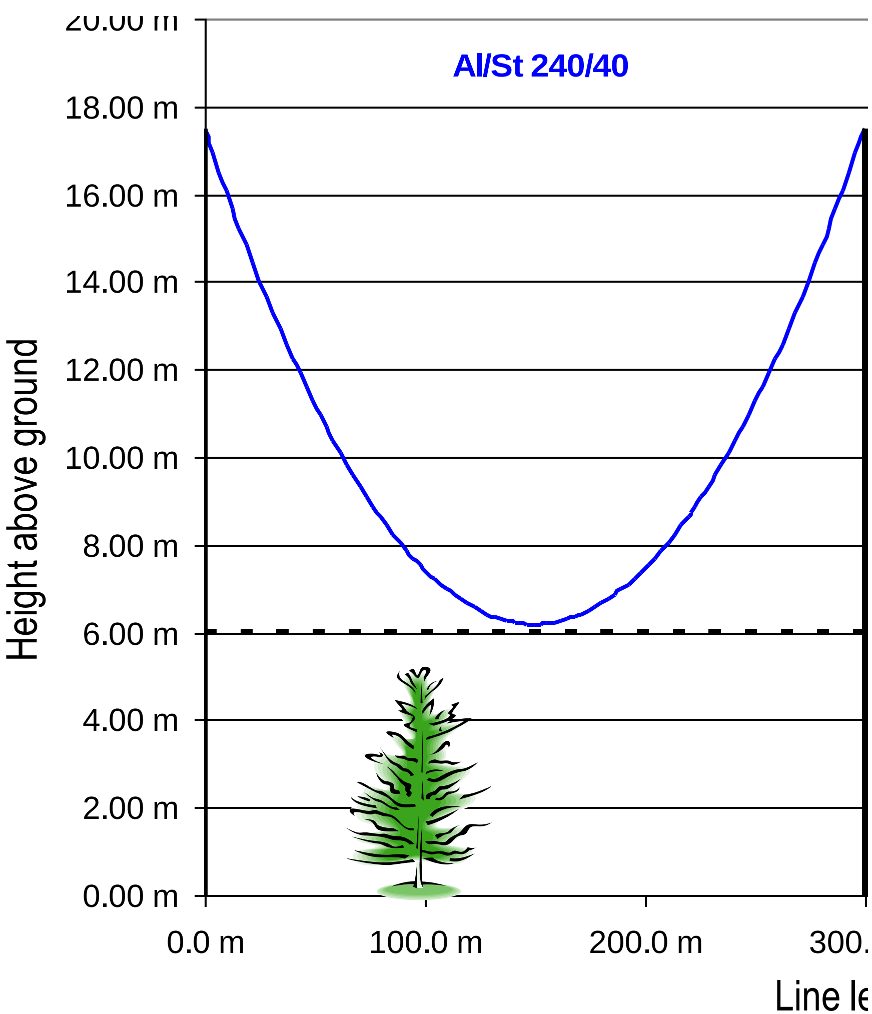
(Design) Criteria for High Capacity Conductors



- **Maximizing ampacity for existing power lines**
  - *Increased revenue*
  - *More useable capacity – improve N-1 ratings on paths*
  - ***More flexibility and responsiveness to serve unexpected load growth, new generation, upgrades on other lines***
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- Good Value
- Complete Reliability for decades of service

Ampacity conditions: 35°C ambient, 0.6 m/s wind, 900 W/m² solar, emissivity 0.5, absorptivity 0.5;
Ice load acc. German ice zone 1, tension 18.5 kN per conductor at-5°C plus ice; line designed for 60°C ACSR

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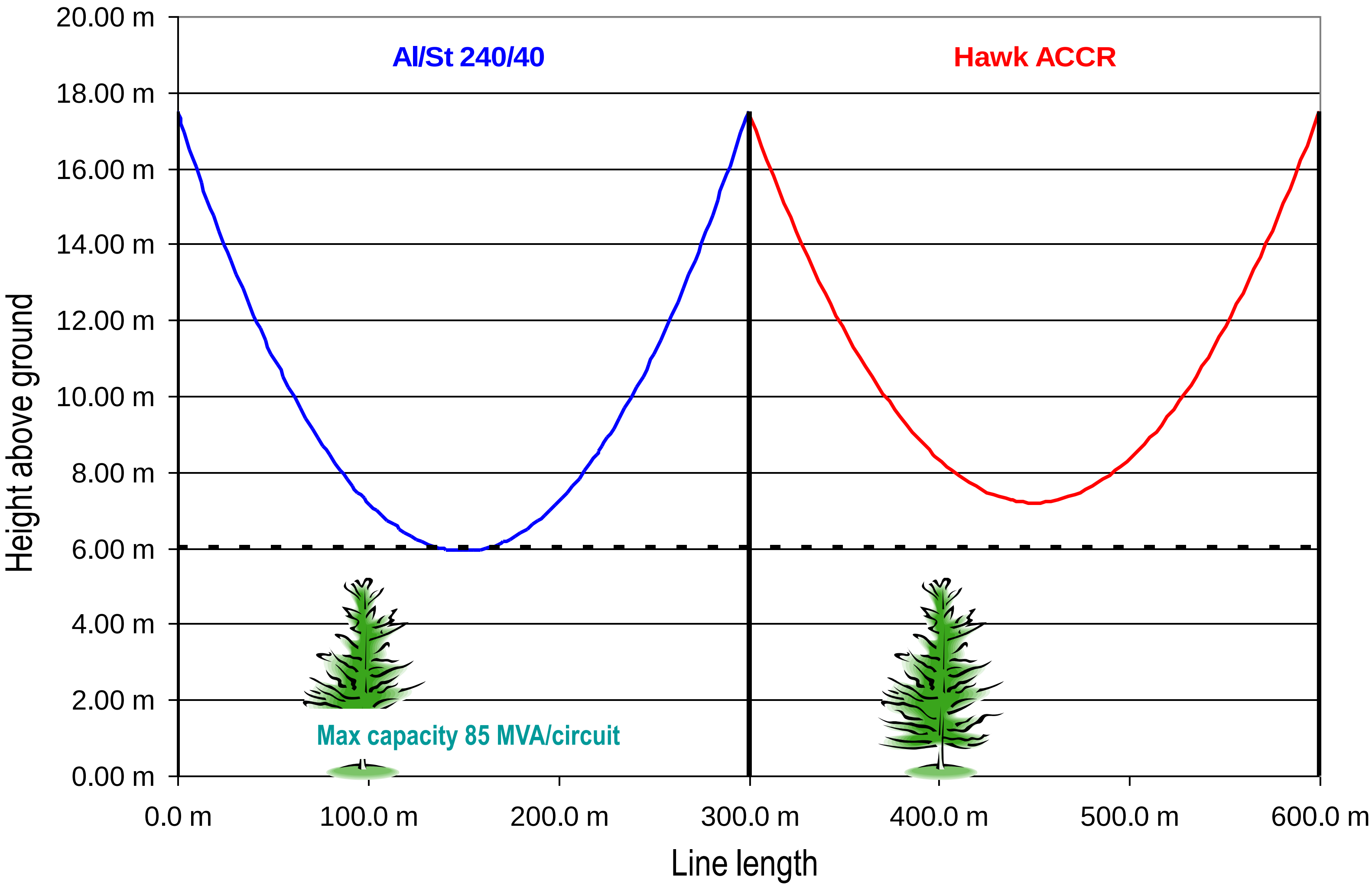
Sag comparison – 110 kV – 85 MVA/Circuit



Ampacity conditions: 35°C ambient, 0.6 m/s wind, 900 W/m² solar, emissivity 0.5, absorptivity 0.5;
Ice load acc. German ice zone 1, tension 18.5 kN per conductor at-5°C plus ice; line designed for 60°C ACSR

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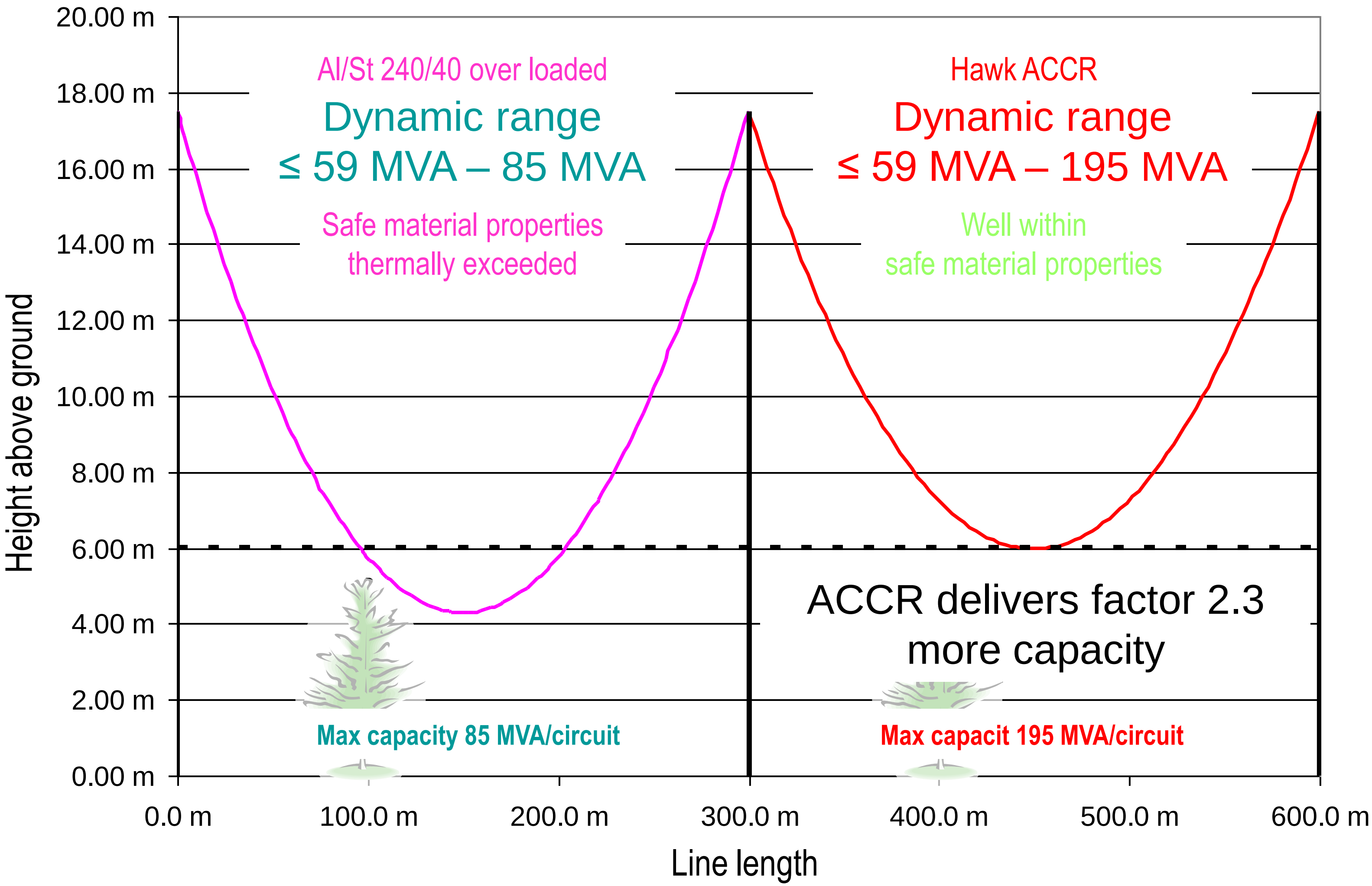
Sag comparison – 110 kV – 195 MVA/Circuit



Ampacity conditions: 35°C ambient, 0.6 m/s wind, 900 W/m² solar, emissivity 0.5, absorptivity 0.5;
Ice load acc. German ice zone 1, tension 18.5 kN per conductor at-5°C plus ice; line designed for 60°C ACSR

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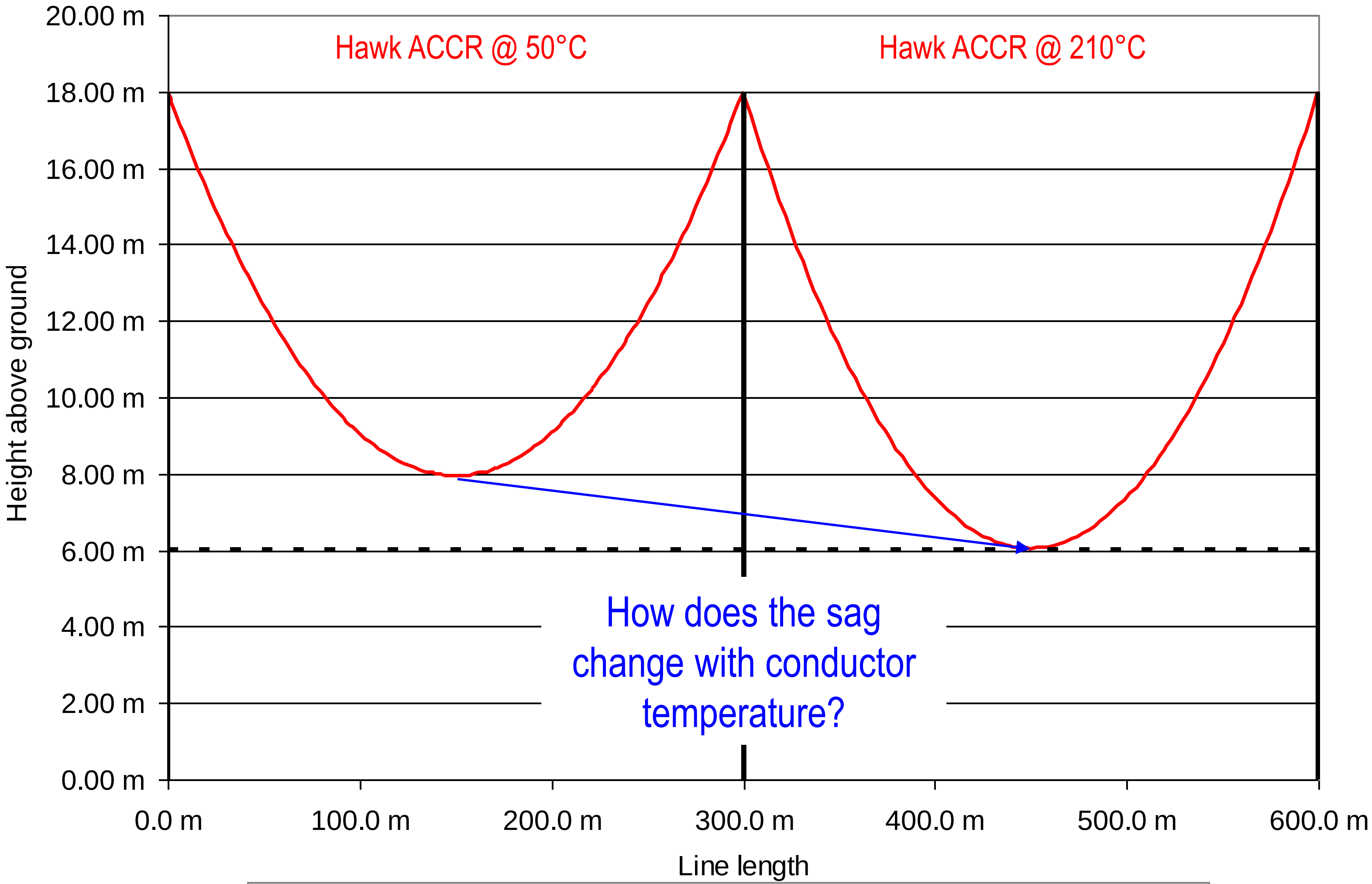
Sag comparison – Hawk ACCR – 50°C vs. 210°C



Ampacity conditions: 35°C ambient, 0.6 m/s wind, 900 W/m² solar, emissivity 0.5, absorptivity 0.5;
Ice load acc. German ice zone 1, tension 18.5 kN per conductor at-5°C plus ice; line designed for 80°C ACSR

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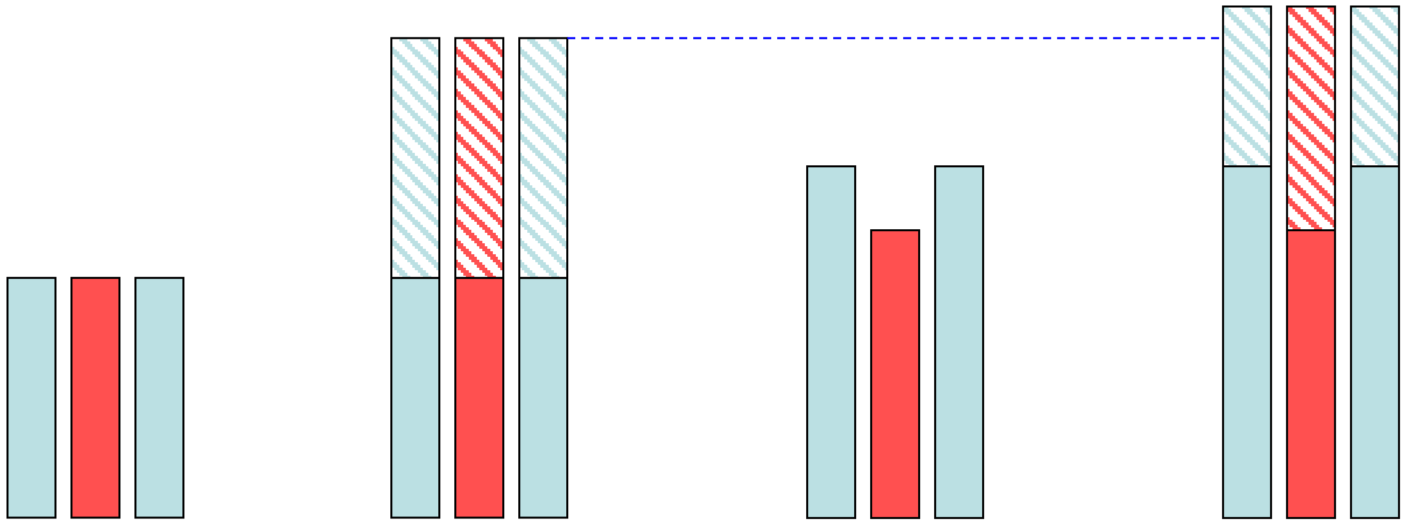
What happens within the conductor?

Attention: This is a thought experiment to highlight some effects!

Effects of moderate temperature (initial case)



ACCR without mechanical load ca. 20°C	ACCR with mechanical load ca. 20°C	ACCR without mechanical load ca. 60°C	ACCR with mechanical load ca. 60°C
		IF it would not be stranded – this is a thought experiment !	Effects: higher sag, relatively more load on the core

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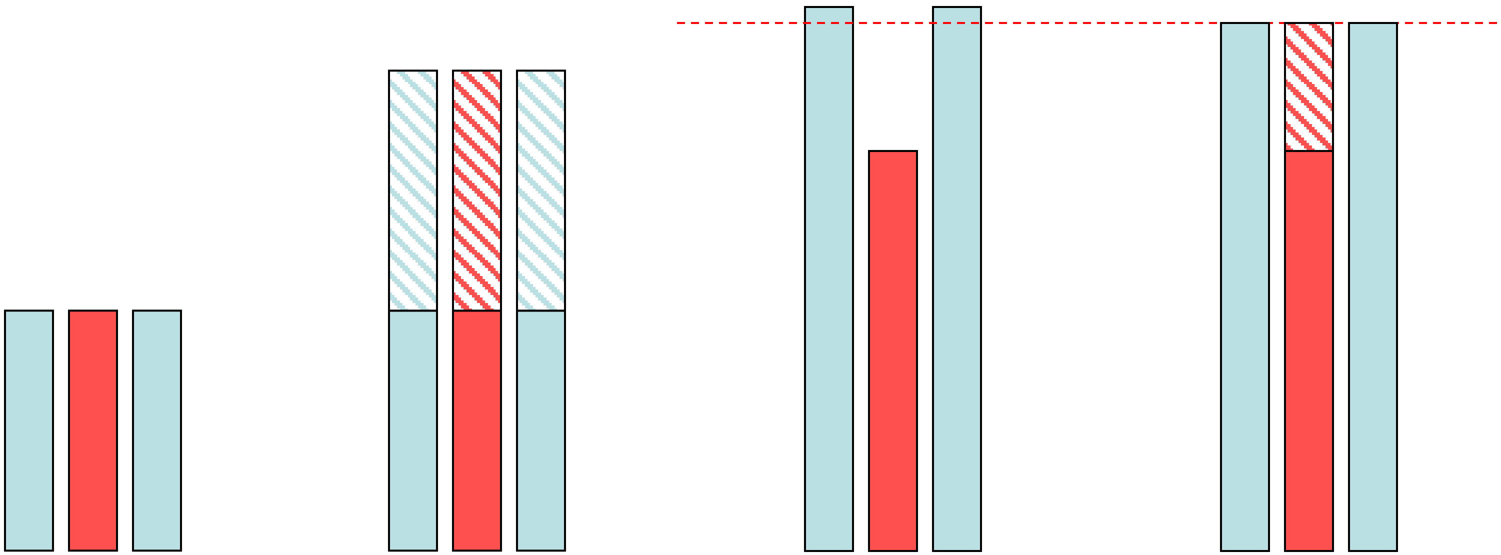
What happens within the conductor?

Attention: This is a thought experiment to highlight some effects!

Effects of high temperature (initial case)



ACCR without mechanical load ca. 20°C

ACCR with mechanical load ca. 20°C

ACCR without mechanical load ca. 210°C

IF it would not be stranded – this is a thought experiment !

ACCR with mechanical load ca. 210°C

Effects: higher sag, tension only on the core, potentially compression on the outer layers

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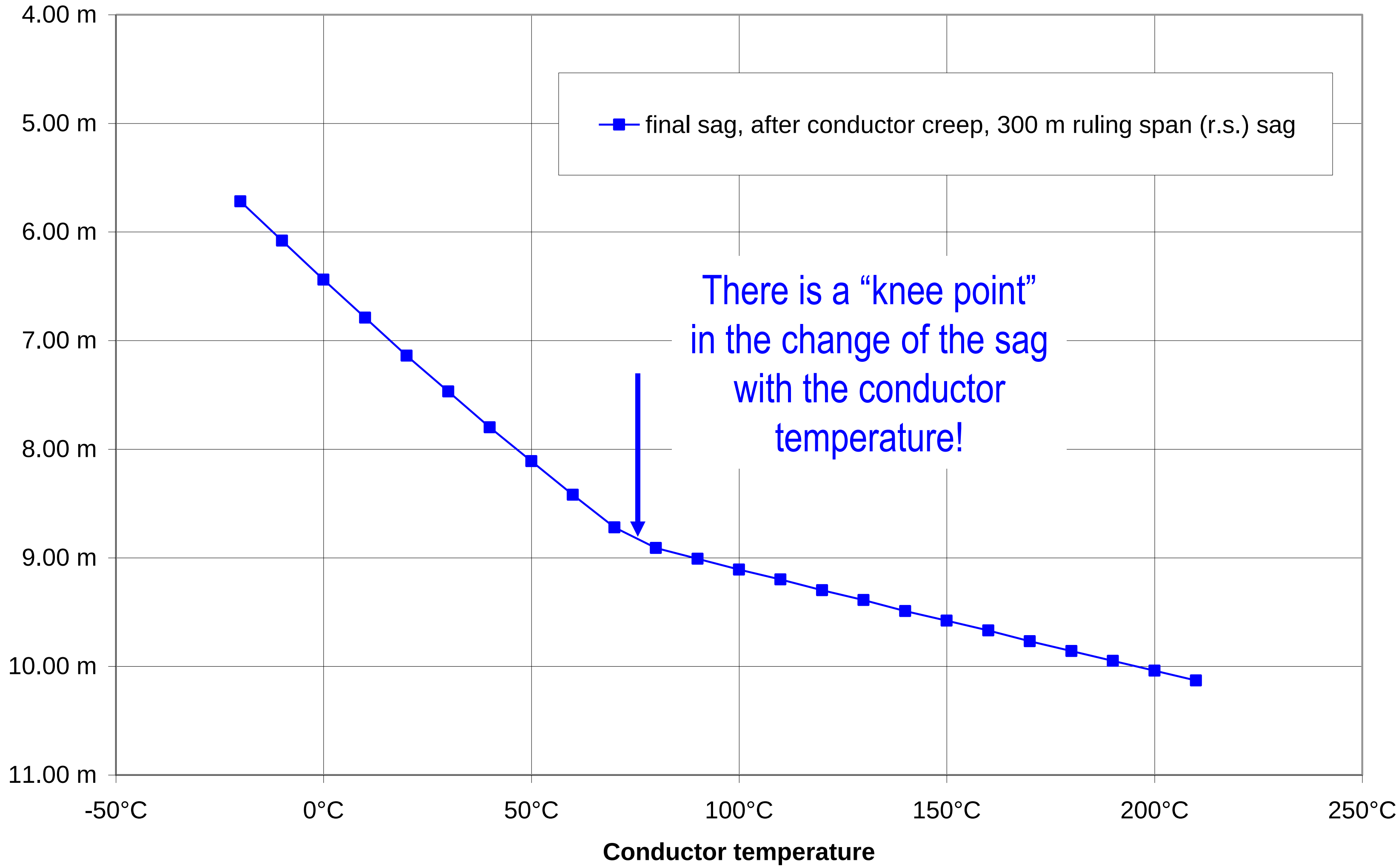
Sag of Hawk ACCR – -50°C up to 210°C



Different stringing then in the slides before! Initial horizontal tension = 14063 N

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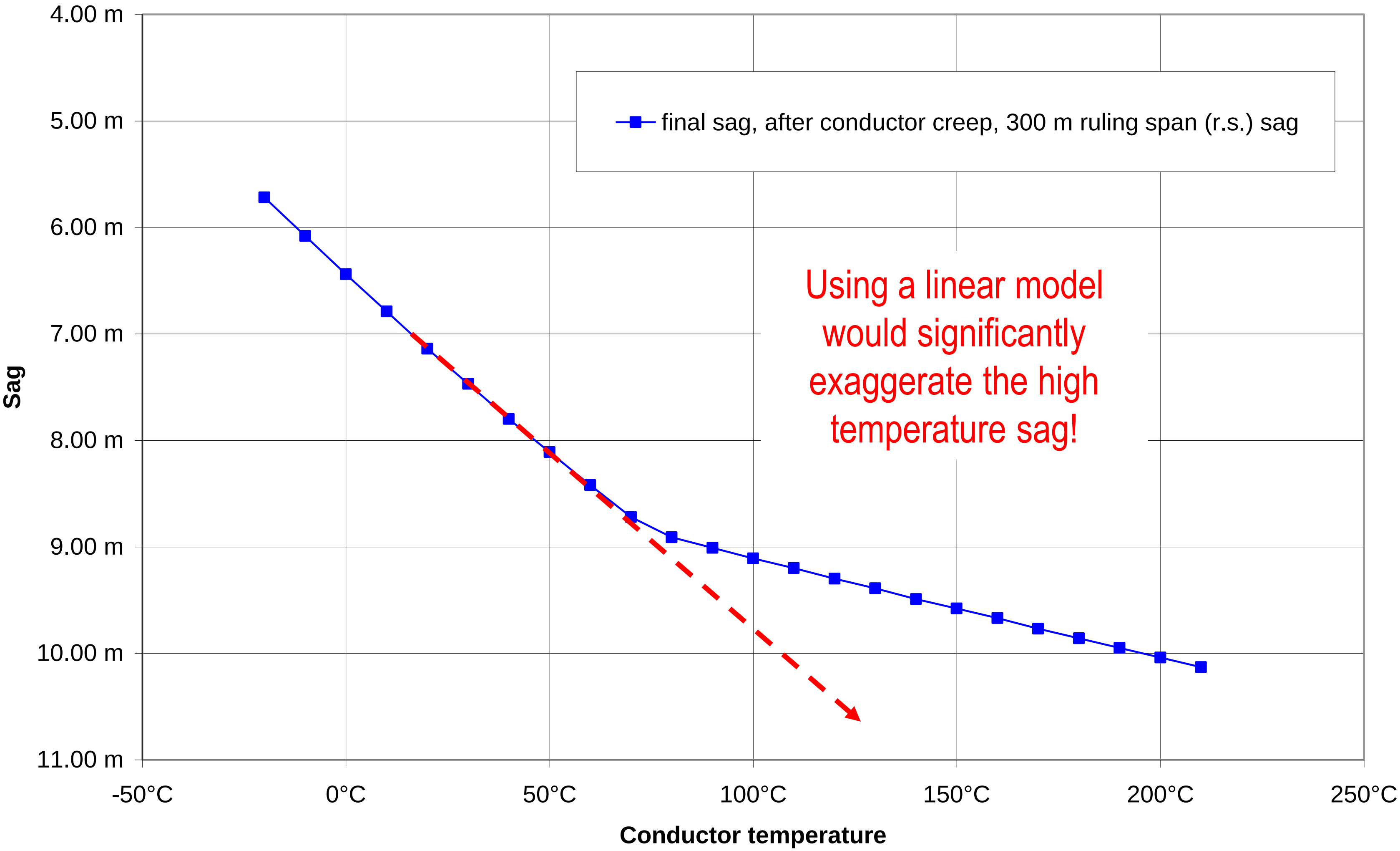
Sag of Hawk ACCR – -50°C up to 210°C



Initial horizontal tension = 14063 N

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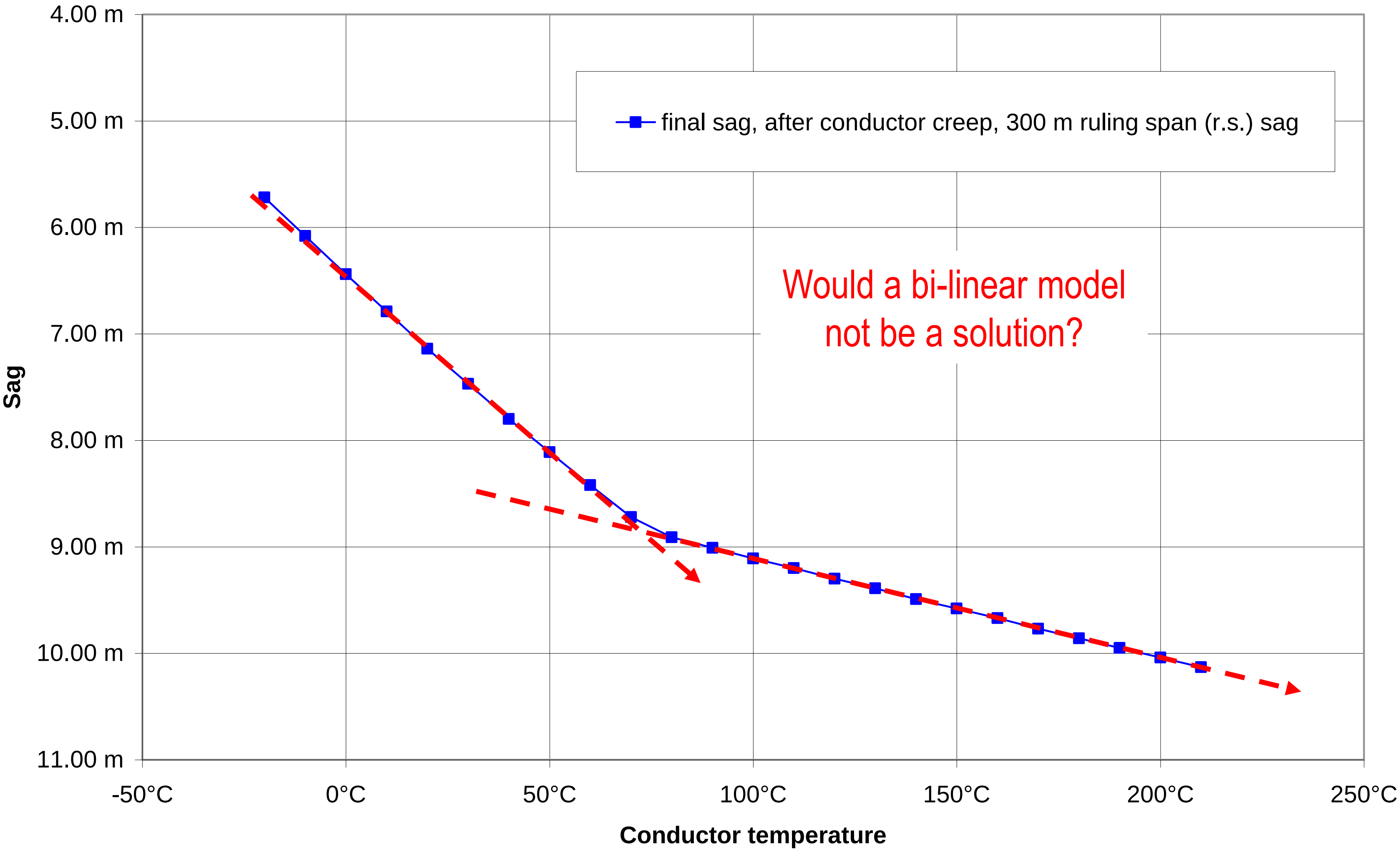
Sag of Hawk ACCR – -50°C up to 210°C



Initial horizontal tension = 14063 N

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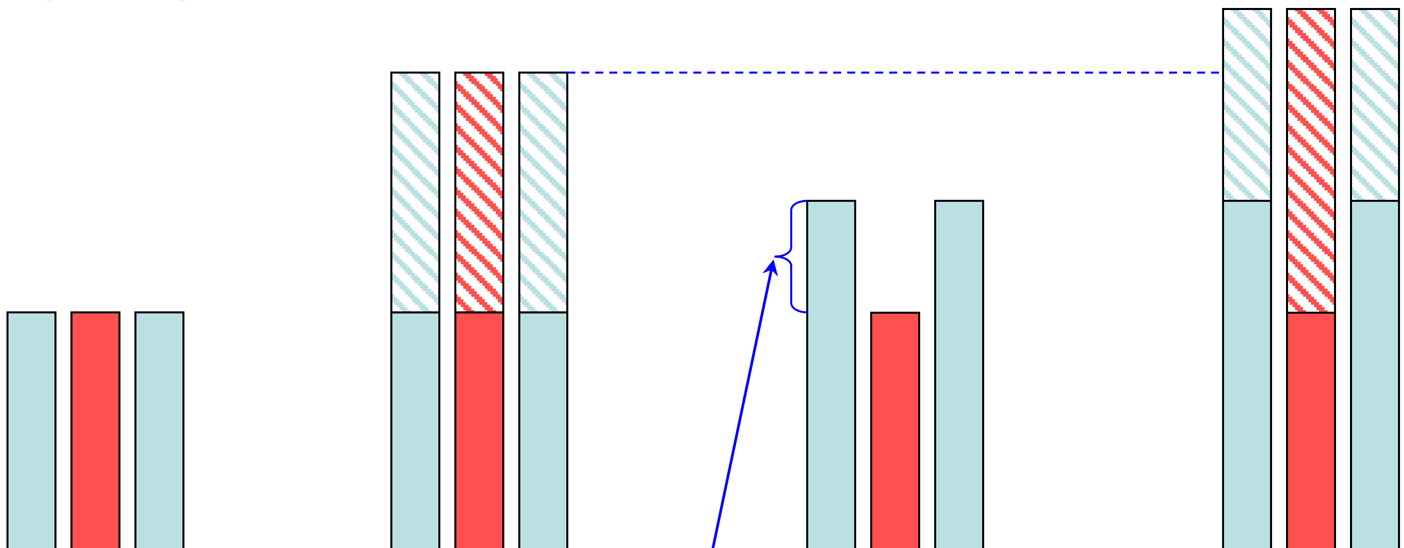
What happens within the conductor?

Attention: This is a thought experiment to highlight some effects!

(Long time) Effects of mechanical load



ACCR without mechanical load ca. 20°C

ACCR with mechanical load ca. 20°C

ACCR after mechanical load ca. 20°C

ACCR again with mechanical load ca. 20°C

This plastic deformation of the aluminum occurs with a low force being applied for a long time (creep) or a high force (e.g. due to ice) even applied just once (load).

IF it would not be stranded – this is a thought experiment !

Effects: higher sag, relatively more load on the core

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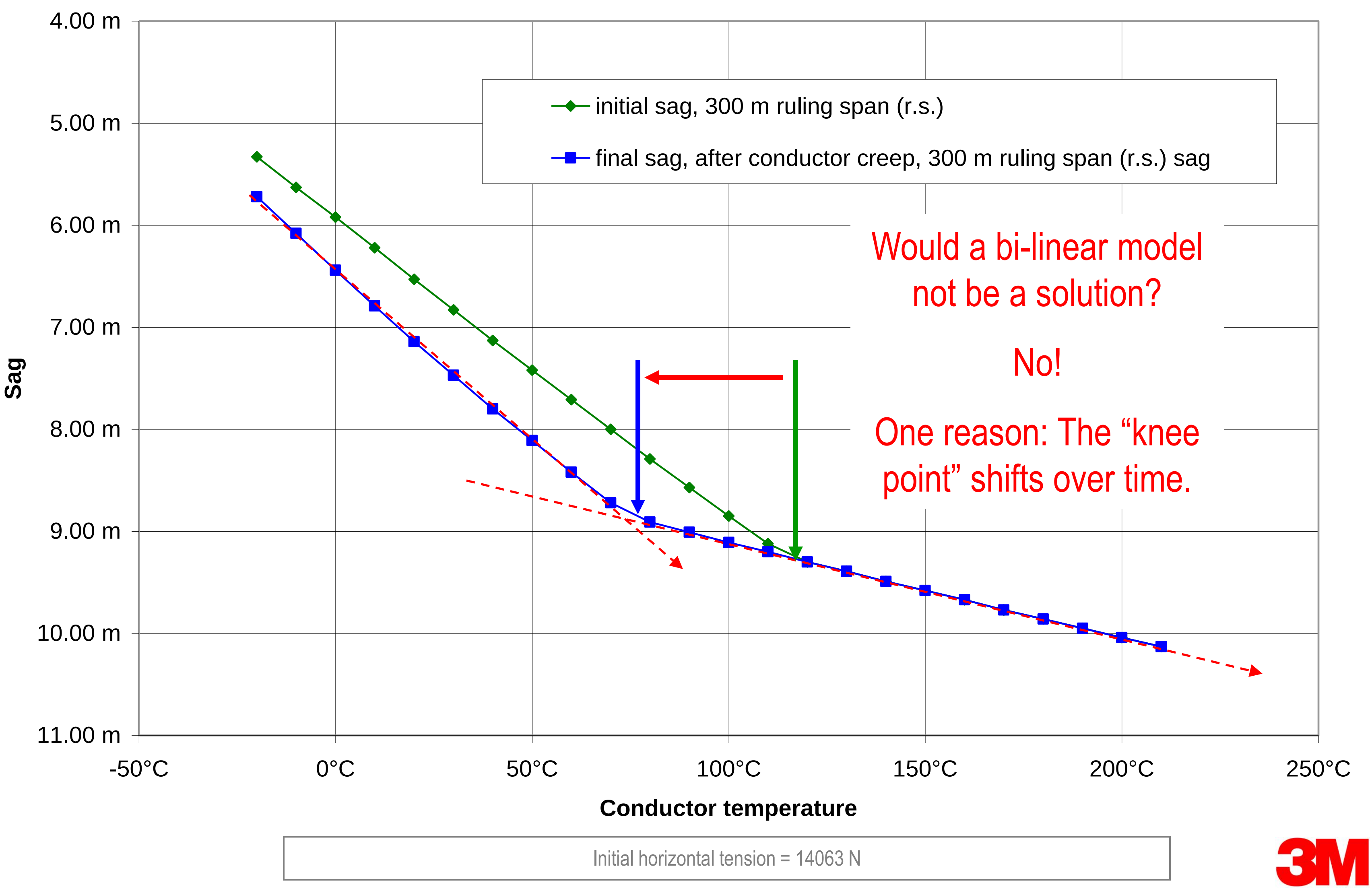
Sag of Hawk ACCR – -50°C up to 210°C



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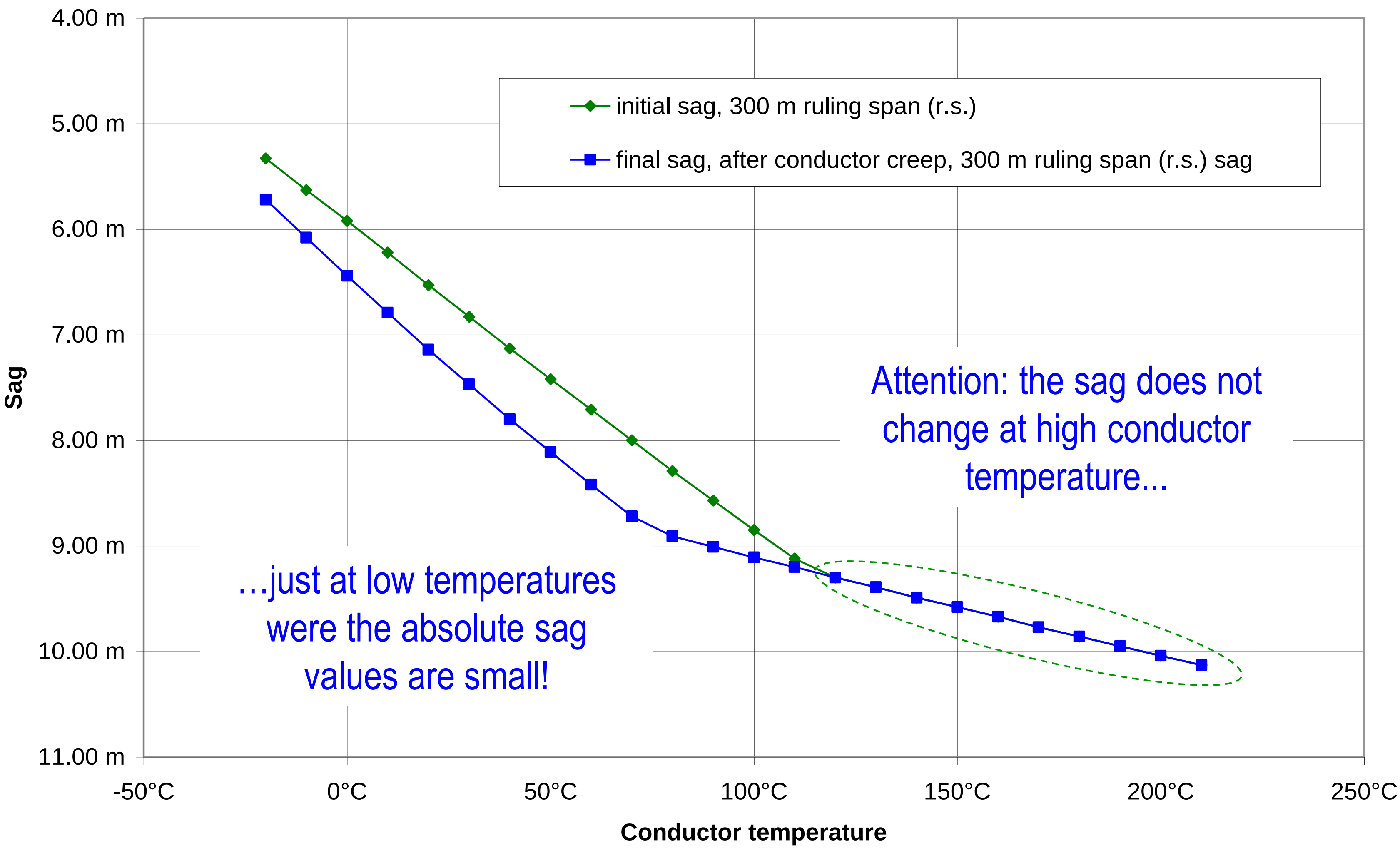
Sag of Hawk ACCR – -50°C up to 210°C



Initial horizontal tension = 14063 N

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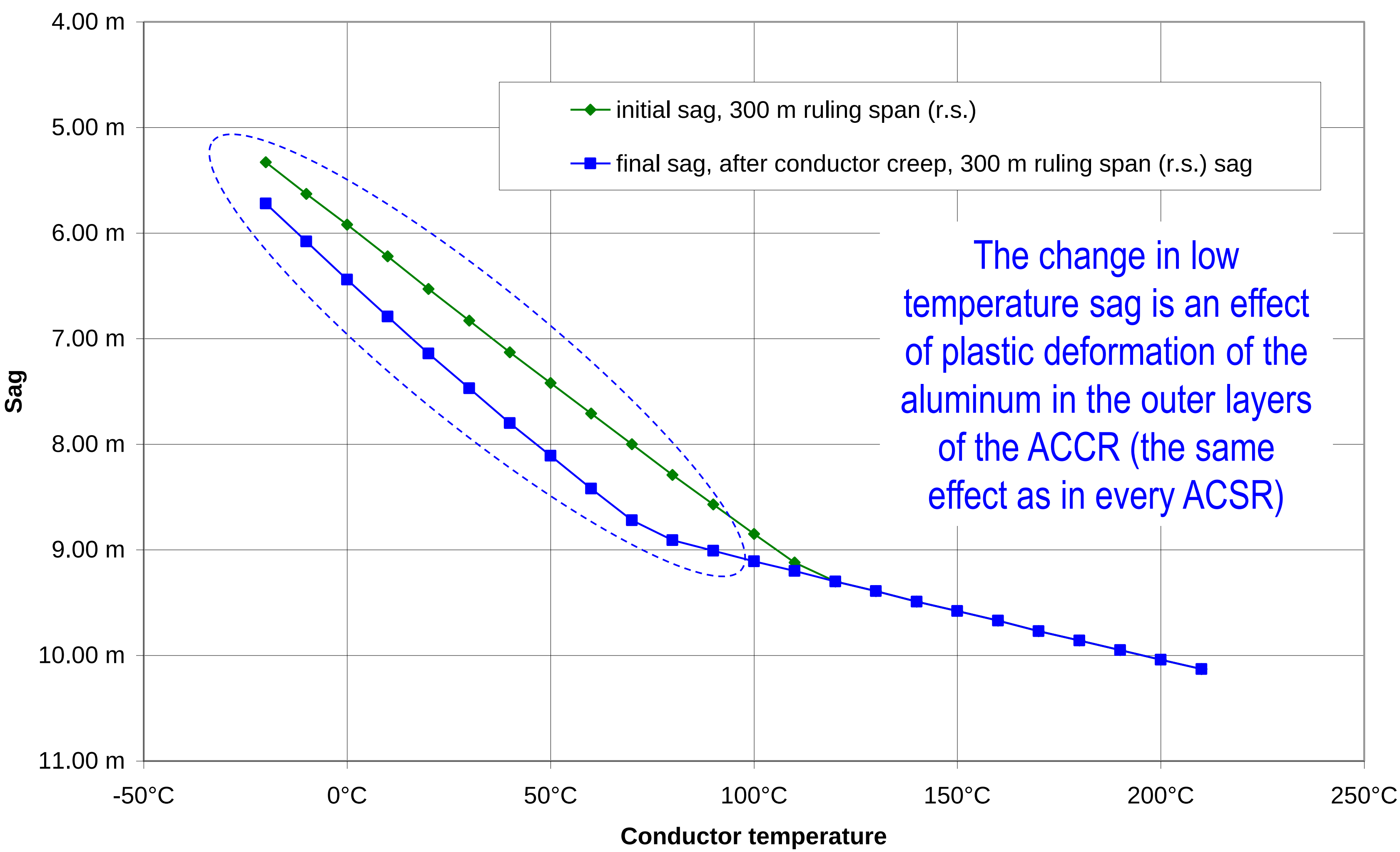
Sag of Hawk ACCR – -50°C up to 210°C



Initial horizontal tension = 14063 N

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Full Parameterized Model

- The alternative to a linear model or a bi-linear model is a full parameterized model
- The input for this model is based on the usual test of the stress strain and the creep behavior of the conductor (in our case ACCR)
- For scientific background see CIGRE paper 324 by Task Force B2.12.3 from June 2007
- The following slides show parameterized data for Hawk ACCR based on measured stress strain and creep data

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Conductor data for a full parameterized model, Hawk ACCR

Cross section area	(mm^2)	276.774	Unit weight	(N/m)	7.77855
Outside diameter	(mm)	21.6408	Ultimate tension	(N)	85405.8

Number of independant wires: 1

(above should be 1 unless have messenger supporting other wires using a spacer)

☐ Conductor is a J-Power Systems GAP type conductor strung with core supporting all tension.

Temperature at which strand data below obtained (deg C) 21.6667

Outer Strands

Final modulus of elasticity (see note below) (MPa/100) 523.07

Thermal expansion coeff. (/100 deg) 0.002304

Polynomial coefficients (all strains in , stresses in MPa, see note

	a0	a1	a2	a3	a4
Stress-strain		406.514	-484.342	346.033	-180.649

	c0	c1	c2	c3	c4
Creep		194.88	-81.6614	-97.5606	50.8556

Note: Final modulus, stress-strain and creep are actual material values multiplied by ratio of outer strand area to total area.

Core Strands (if different from outer strands)

Final modulus of elasticity (see note below) (MPa/100) 317.799

Thermal expansion coeff. (/100 deg) 0.00063

Polynomial coefficients (all strains in , stresses in MPa, see note

	b0	b1	b2	b3	b4
Stress-strain		327.818	-81.1994	97.5606	-50.8556

	d0	d1	d2	d3	d4
Creep		327.818	-81.1994	97.5606	-50.8556

Note: Final modulus, stress-strain and creep are actual material values multiplied by ratio of core strand area to total area.

Bimetallic Conductor Model...

Aluminum has a larger thermal expansion coefficient than steel. If Aluminum is used as the outer material over a steel core there is a temperature transition point at which the aluminum is no longer under tension.

Select the behavior you want for temperatures above the transition point

- (•) Use behavior from Criteria/Bimetallic Conductor Model
- ( ) Aluminum does not take compression at high temperature (Bird Cage)
- ( ) Aluminum can go into compression at high temperature

VirtualStress = ActualStress * Ao / At
Ao = cross section area of outer strands
At = total cross section area of entire conductor (outer + inner strands)

Maximum virtual compressive stress (MPa) 68947.4

Thermal Rating Properties

Resistance at two different temperatures

Resistance (Ohm/km)	0.117998	at	(deg C)	25
Resistance (Ohm/km)	0.141362	at	(deg C)	75

Emissivity coefficient		0.5
Solar absorption coefficient		0.5
Outer strands heat capacity	(Watt-s/m-deg C)	628.937
Core heat capacity	(Watt-s/m-deg C)	43.7008

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Sag-Tension Table for Hawk ACCR 477-T16

Comparing to Al/St 240/40, 400m Span

#	Description	Al/St 240/40 Max. Tens. (N)	Al/St 240/40 Hori. Tens. (N)	Al/St 240/40 % UL	Al/St 240/40 C (m)	Al/St 240/40 R.S. Sag (m)	Hawk ACCR (238/39) Max. Tens. (N)	Hawk ACCR (238/39) Hori. Tens. (N)	Hawk ACCR (238/39) % UL	Hawk ACCR (238/39) C (m)	Hawk ACCR (238/39) R.S. Sag (m)
	---Weather Case---	-----R.S. Final Cond.----- --------After Creep--------					-----R.S. Final Cond.----- --------After Creep--------				
1	everyday 10°C	15369	15249	18	1593	12.57	14131	14045	17	1806	11.09
2	Ice E1	25850	25631	30	1531	13.08	25669	25494	30	1706	11.74
3	40°C + wind 1	16630	16469	19	1432	13.99	16090	15964	19	1591	12.58
4	-20 C	17007	16899	20	1765	11.34	15869	15792	19	2030	9.86
5	-10 C	16409	16297	19	1702	11.76	15229	15149	18	1948	10.28
6	0 C	15869	15752	18	1645	12.17	14652	14569	17	1873	10.69
7	10 C	15369	15249	18	1593	12.57	14131	14045	17	1806	11.09
8	20 C	14915	14791	17	1545	12.96	13657	13567	16	1744	11.48
9	30 C	14489	14361	17	1500	13.35	13221	13128	15	1688	11.86
10	40 C	14100	13969	16	1459	13.73	12819	12724	15	1636	12.24
11	50 C	13736	13601	16	1421	14.10	12451	12353	15	1588	12.61
12	60 C	13396	13258	15	1385	14.47	12109	12008	14	1544	12.97
13	70 C	13081	12939	15	1352	14.83	11791	11688	14	1503	13.33
14	80 C	12786	12641	15	1320	15.18	11499	11392	13	1465	13.68
15	90 C						11[illegible]76	11268	13	1449	13.83
16	100 C						11287	11178	13	1437	13.94
17	110 C						11196	11086	13	1425	14.06
18	120 C						11108	10998	13	1414	14.17
19	130 C						11023	10911	13	1403	14.28
20	140 C						10940	10828	13	1392	14.39
21	150 C						10858	10745	13	1381	14.50
22	160 C						10775	10661	13	1371	14.62
23	170 C						10696	10581	13	1360	14.73
24	180 C						10618	10503	12	1350	14.84
25	190 C						10543	10426	12	1340	14.95
26	200 C						10468	10351	12	1331	15.06
27	210 C						10394	10276	12	1321	15.17

625 A* (Al/St 240/40, row 14)

628 A* (Hawk ACCR, row 14)

1182 A* (Hawk ACCR, row 27)

Higher Ampacity

Lower Tension

Lower Sag

3M ACCR: lower tension, lower sag, higher ampacity

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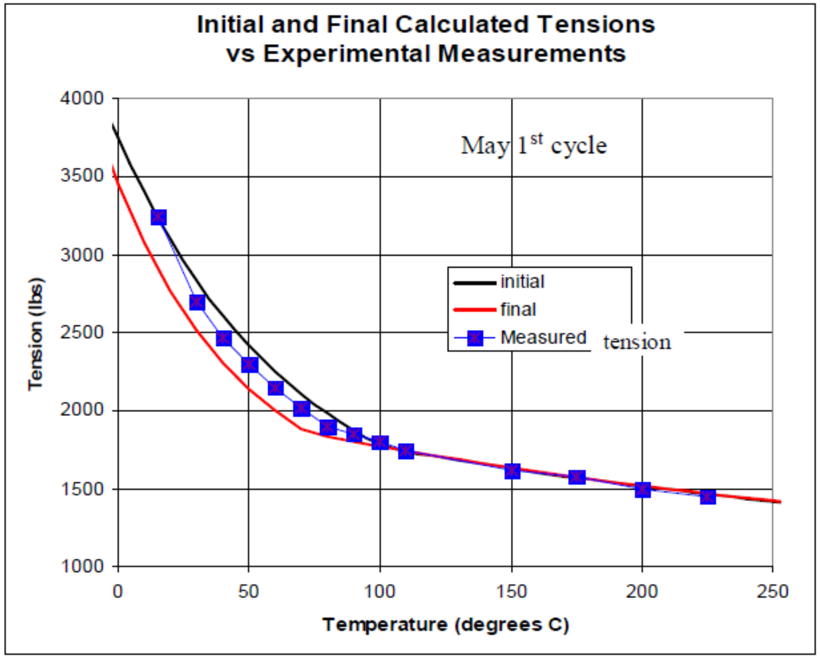
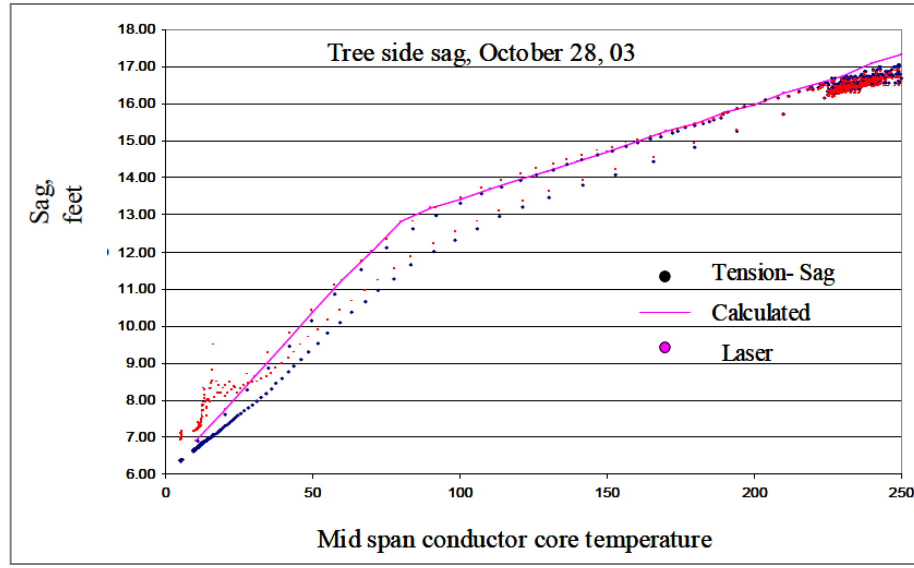
*) nach IEEE Std. 738-2006, 35°C, 0.6 m/s, 875 W/m², 0.5 Emissionskoeffizient und Absorptionskoeffizient

Comparing reality and theory



Tension of Hawk ACCR 477-T16 measured (10 months after installation) with a CAT-1 system compared with prediction (based on a fully parameterized model)*



Sag of Hawk ACCR 477-T16 measured (with a laser) an calculated from tension values compared with prediction (based on a fully parmeterized model)*

*) see ACCR test report # 53; www.3m.com/accr

- Very good fit between theory and reality

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Thank You !

3M Aluminum Conductor Composite Reinforced
More amps on the same size conductors, for your toughest transmission challenges

What can we do for you?

Please contact:
Dr. Jan Thomas Krapp
Senior Technical Service Specialist Europe
High Capacity Conductors

3M Deutschland GmbH
Electrical Markets Division Laboratory
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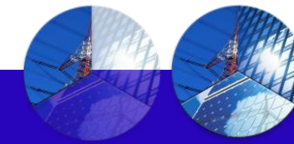

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