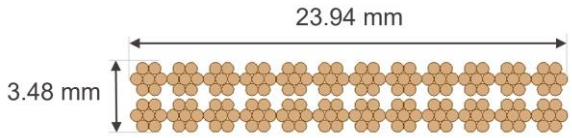
Quench analysis: 0D estimate

Conductor layout:



Conductor cross-section	94.4 mm^2
Cable	64.7 mm^2 (68.5%)
Copper	32.3 mm^2 (34.2%)
Noncopper	32.3 mm^2 (34.2%)
Impregnation	18.7 mm^2 (11.8%)
Insulation	11.1 mm^2 (19.8%)

Strand diameter	0.7 mm
Copper-noncopper ratio	1
RRR	150
Number of strands	24*7 = 168
Total width	24.34 mm
Total height	3.88 mm
Insulation thickness	0.2 mm

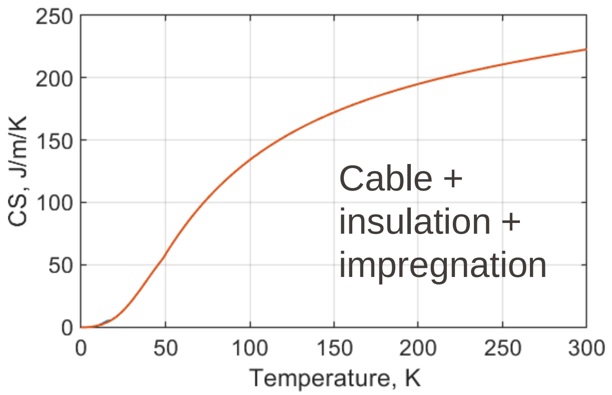
Operating current	18 kA
J eng	182 A/mm^2
J cu	533 A/mm^2
Inductance	0.13 H
Stored energy	21.1 MJ
Discharge voltage (max)	1 kV
Time constant τ	2.34 s
Delay time t_d	16 ms

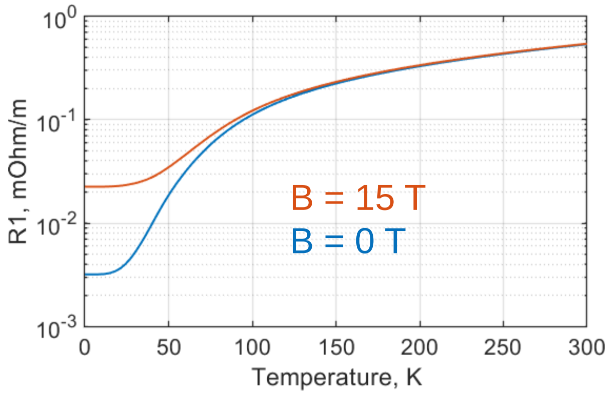
Quench analysis: 0D estimate

Adiabatic analysis:

$C(T)S\frac{\partial T}{\partial t} = I^2 R_1(T,B)$ [W/m]

- Conductor cross-section isothermal
- Current flow in copper
- Size of normal zone to reach 100 mV at 18 kA: 1.7 m (0 T), 0.2 m (15 T)
- $T(t=0) = 8$ K:
  $T_{max} = 397$ K at B = 0 T constant
  $T_{max} = 1090$ K at B = 15 T constant
  $T_{max} = 1060$ K for B = k x I
- I = 17 kA, V = 1.5 kV, tau = 1.47 s:
  $T_{max} = 100$ K at B = 0 T constant
  $T_{max} = 262$ K at B = 15 T constant
  $T_{max} = 243$ K for B = k x I

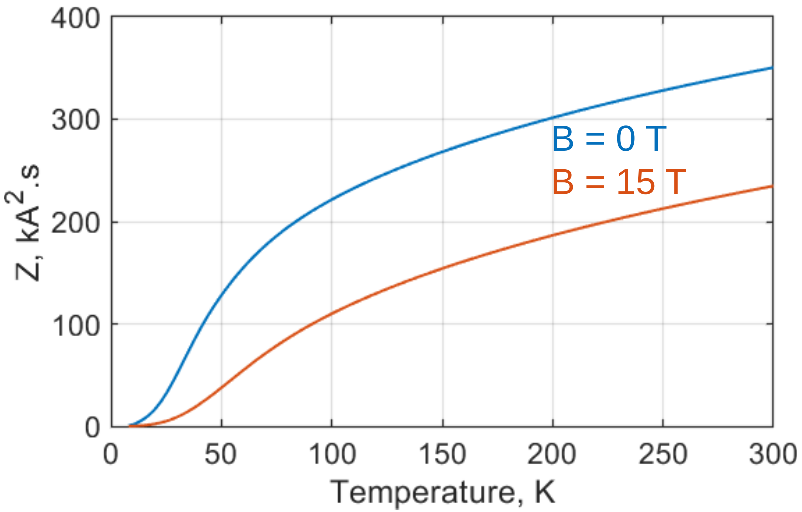




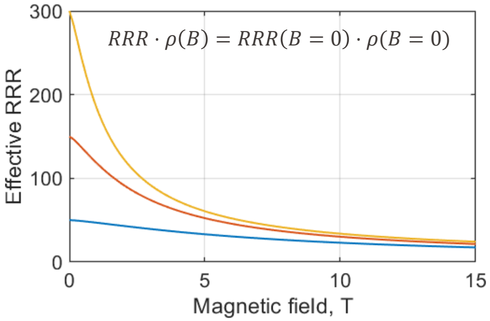
Quench analysis: 0D estimate

Constant B:

- $Z(T) = \int_{T_0}^{T} \frac{C(x)S}{R_1(x,B)} dx$
- Quench integral:
  $\int I^2 dt = I^2(t_d + \tau/2) \approx EI/V = LI^3/2V$
  = 384 kA^2.s at 18 kA, 1.0 kV
  = 218 kA^2.s at 17 kA, 1.5 kV



- Cross-check the actual effect of magnetoresistance?
- 3-D model to be prepared to quantify impact of thermal conductivity in transverse and longitudinal directions, though strong impact on Tmax is not expected

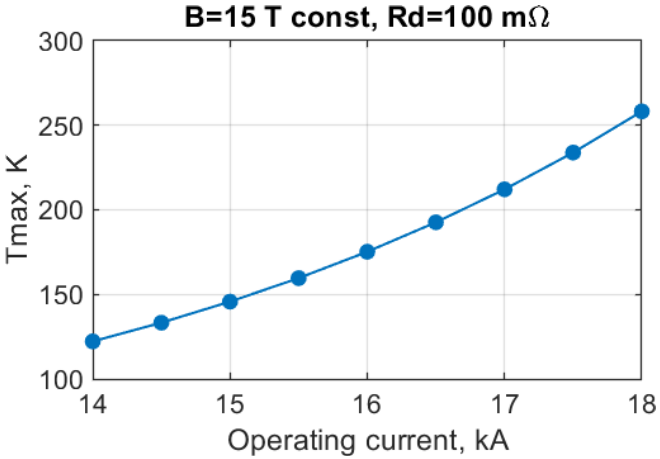


RRR ~ 20

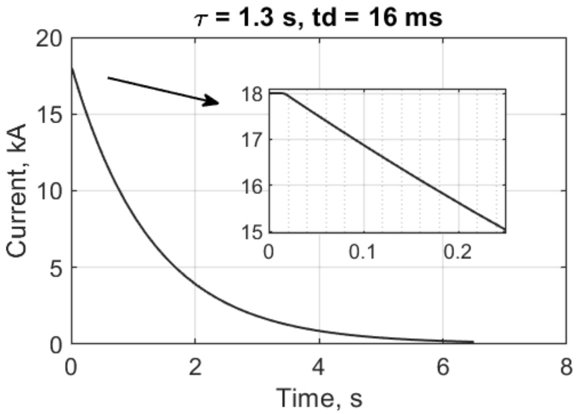
Quench analysis: 0D estimate

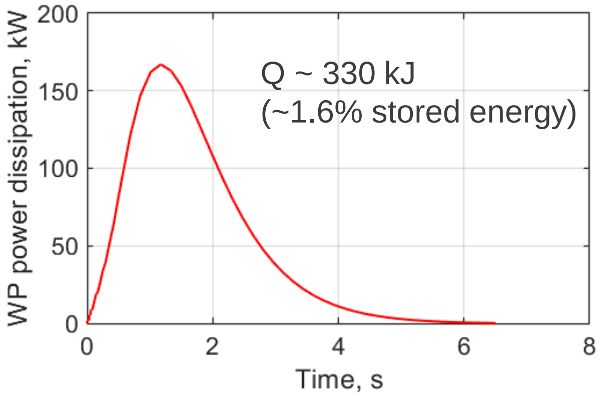
Rd, mΩ	**100**	
τ, s	1.3	
I, kA	18.0	17.0
E, MJ	21.1	18.8
V, kV	1.8	1.7
Tmax*, K	258	212

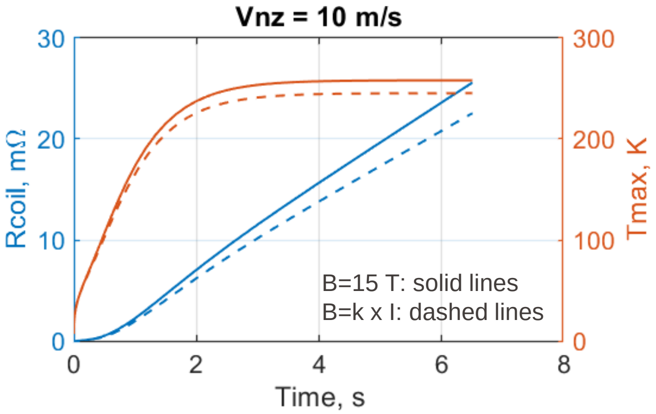
* @ B = 15 T constant

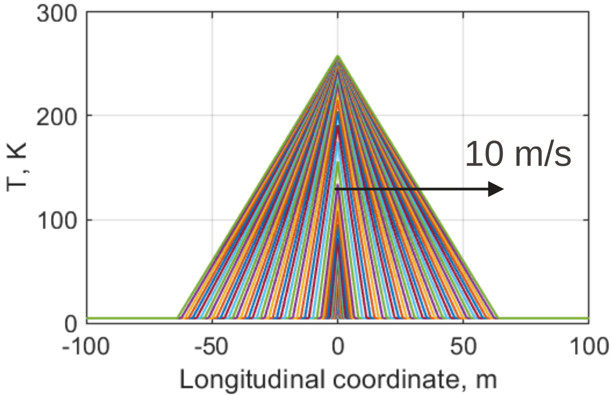


Quench analysis: 0D estimate









Quench analysis: 0D estimate

Neglected terms so far:

- Thermal conductivity in longitudinal and transverse direction → lower Tmax
- AC loss heating due to Bdot, thus faster current decay → lower Tmax
- Higher resistance due to Rcoil, thus faster current decay → lower Tmax
- Impact of iron on coil inductance during quench? ~20% higher L at low B?

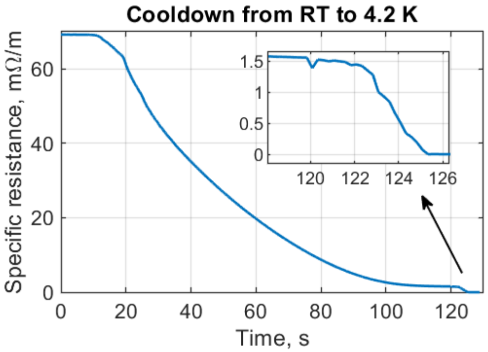
Quench analysis: Copper RRR

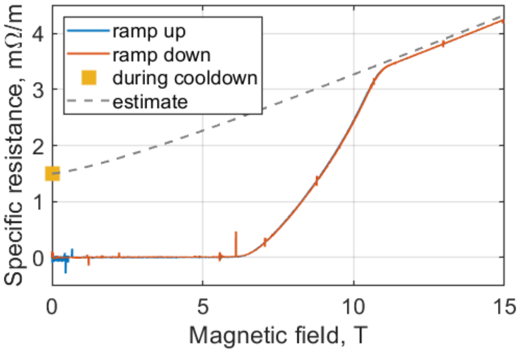
- OD 0.7 mm, cnc ~1.2, Scu 0.21 mm^2, RRR

Likely 50-100, but best effort

BRUKER

- Resistance estimate for RRR = 50:
  ~80 mΩ/m at 293 K → ~1.5 mΩ/m at 4 – 20 K → ~4.3 mΩ/m at 4 K, 15 T
- Measurements on **non-reacted** 0.5 m-long sample
- Impact of heat-treatment…





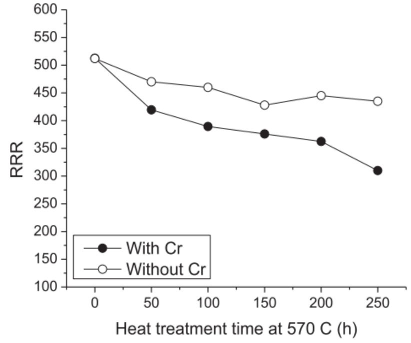
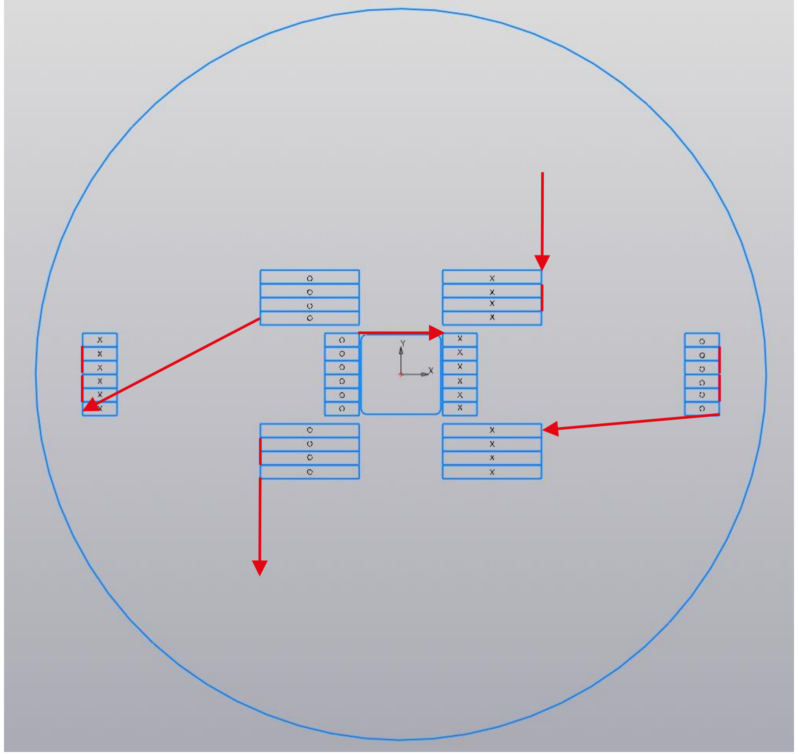


Figure 6. RRR of the JASTEC strand as function of heat treatment time at 570 °C (first step) for samples with and without plated Cr.

https://iopscience.iop.org/article/10.1088/1361-6668/aa67ab

Quench analysis: towards 3D model



Coil splicing layout?

Cooling interface?