Fermilab

TS-SSC 90-51

8/31/90

To: Gregg Kobliska
From: Jim Strait
Subject: Steel alloy of 50 mm SSC dipoles

We originally selected 316LN for the skins for the 50 mm SSC collider dipole because it has the highest room temperature yield strength in the annealed state of among the 304 and 316 alloys. Because of the difficulty you encountered in procuring 316LN and your suggestion that we reconsider the use of 304LN, I have reviewed their relative properties. Data from the NBS (attached) shows for an average of 19 samples of 316LN a room temperature yield strength of 50 kpsi with a two standard deviation spread of ±23 kpsi. For 166 samples of 304(N, LN, HN, LHN) the average yield strength is 41 kpsi with a two standard deviation spread of ±25 kpsi. Given the spread in the strength of randomly collected samples, we should specify a minimum yield strength in the annealed state of 45 kpsi for either alloy. Since this is readily achievable with 304LN, I recommend that we procure 304LN with a 45 kpsi minimum yield strength specification. (I attach for reference a copy of e-mail from Jon Zbasnik that also suggests that 304LN is adequate. The concern expressed about possible large bending stresses at the end plate have been addressed by design changes at the end and are, I believe, irrelevant now.)

cc: R. Bossert, T. Bush, J. Carson, R. Coombes, S. Delchamps, C. Goodzeit, N. Hassan, R. Jayakumar, W. Koska, R. Palmer, E.G. Pewitt, P. Sanger, M. Wake, J. Zbasnik

STRUCTURAL MATERIALS FOR SUPERCONDUCTING MAGNETS

MATERIAL	PROPERTY
AISI 316LN STAINLESS STEEL (ANNEALED)	TENSILE YIELD STRENGTH, AVERAGE

TENSILE YIELD STRENGTH, AVERAGE, OF ANNEALED 316LN STAINLESS STEEL

Temp., K	MPa	(ksi)
4	988.9	(143.3)
20	935.5	(135.7)
40	871.7	(126.4)
60	811.2	(117.7)
77	762.4	(110.6)
80	754.0	(109.4)
100	700.1	(101.5)
120	649.5	(94.2)
140	602.2	(87.3)
160	558.2	(81.0)
180	517.4	(75.0)
200	480.0	(69.6)
220	445.9	(64.7)
240	415.0	(60.2)
260	387.4	(56.2)
273	373.0	(54.1)
280	363.2	(52.7)
300	342.2	(49.6)

TENSILE YIELD STRENGTH DATA FOR GRAPH

Test Temp., K	Number of Data Points
4	20
77	9
111	1
153	1
173	1
193	3
223	1
293/300	19

TOTAL NUMBER OF DATA POINTS: 55

COEFFICIENTS

$b_0 = 1.0026 \times 10^3$

$b_1 = -3.4301$

$b_2 = 4.1165 \times 10^{-3}$

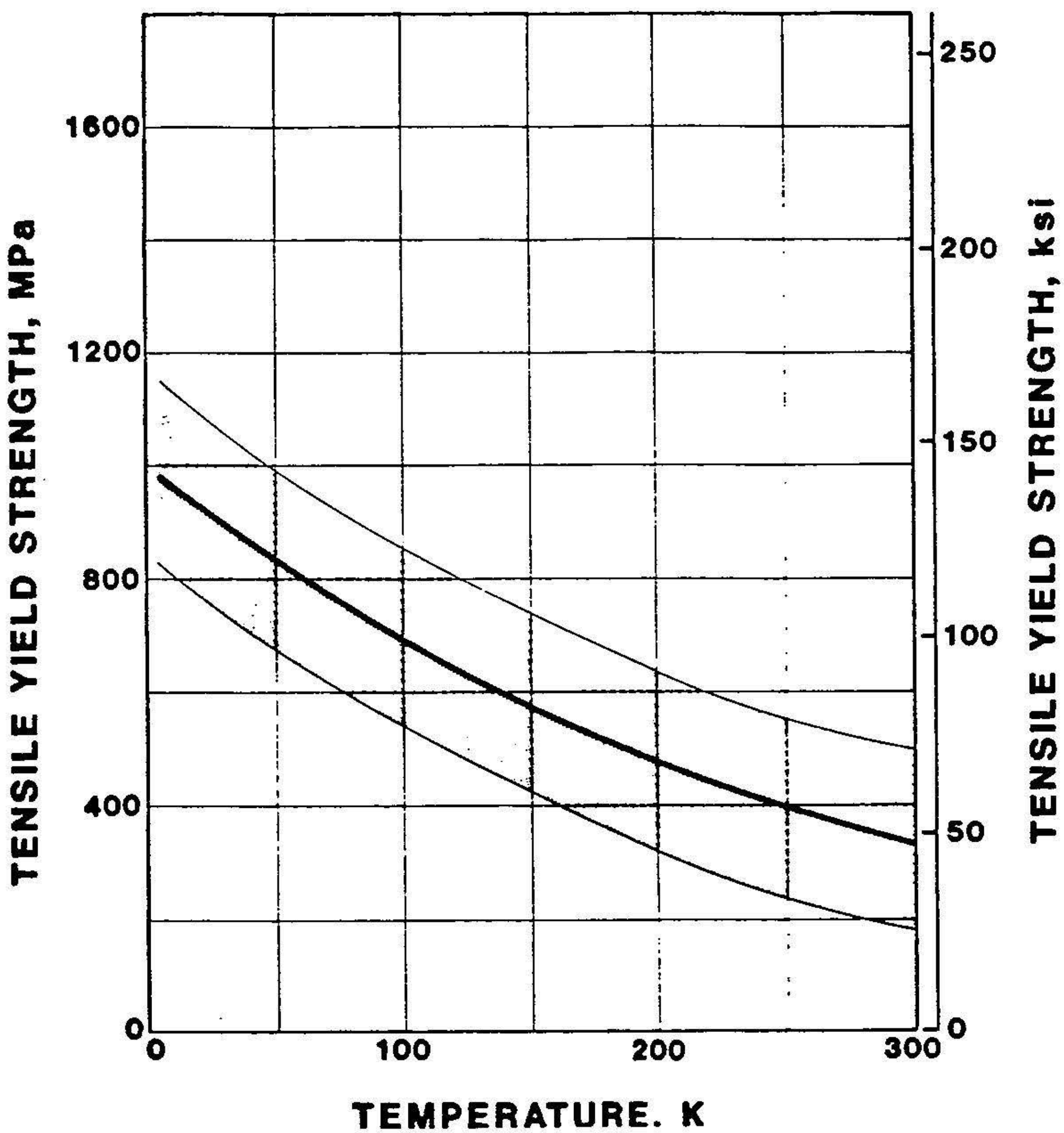
YIELD STRENGTH (MPa) = $b_0 + b_1T + b_2T^2$ (T in K)

TENSILE YIELD STRENGTH DATA AT 4 K

Temperature, K	YS, MPa	YS, (ksi)	
4	970	(141)	(Mean of values from 12 specimens)
4	931	(135)	
4	1094	(159)	
4	980	(142)	
4	1020	(148)	(Mean value from 3 transverse and 2 longitudinal tests)
4	1020	(148)	
4	1160	(168)	
4	815	(118)	
4	920	(133)	

STRUCTURAL MATERIALS FOR SUPERCONDUCTING MAGNETS

MATERIAL	PROPERTY
AISI 316LN STAINLESS STEEL (ANNEALED)	TENSILE YIELD STRENGTH, AVERAGE

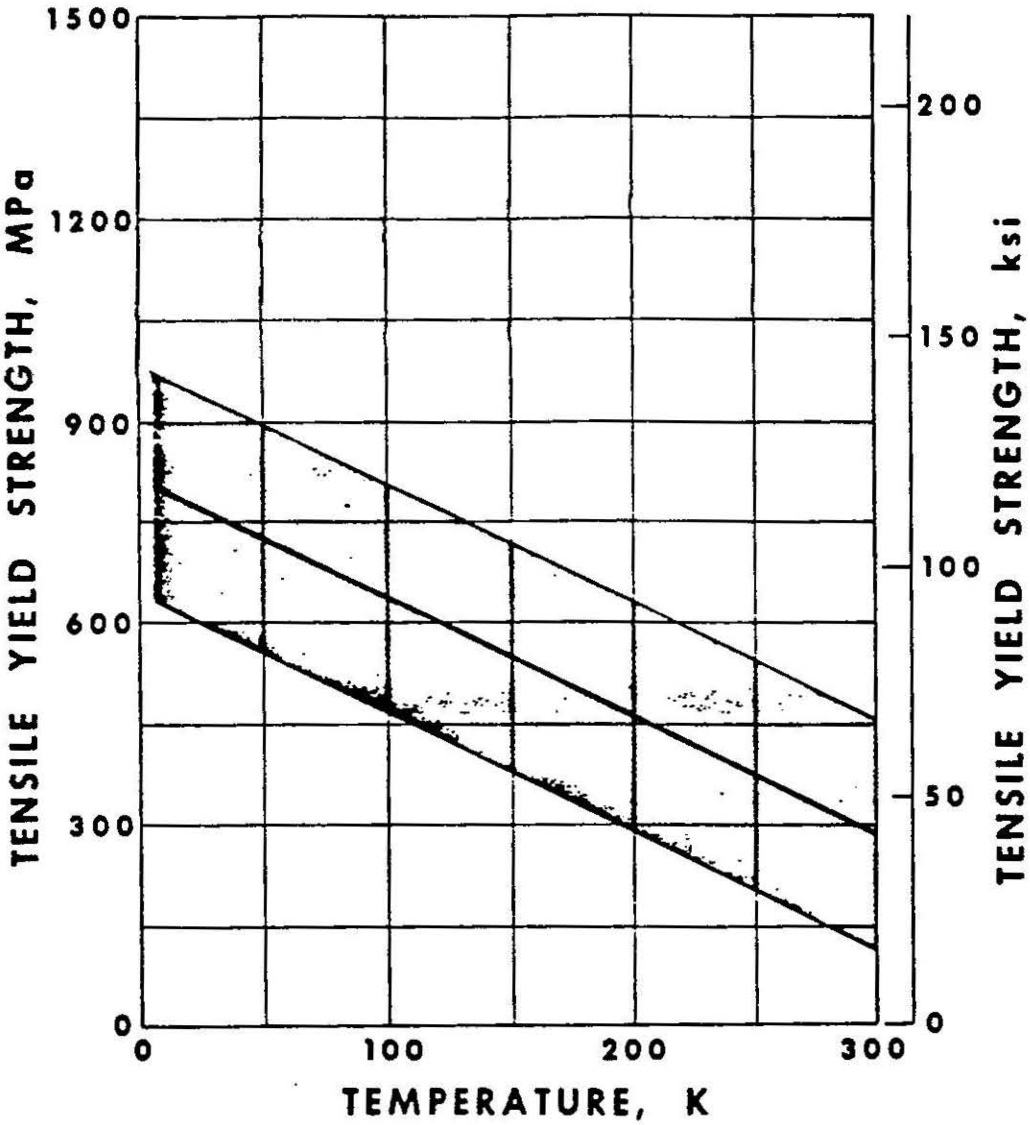


AVERAGE VALUE CURVE

The scatter band represents two standard deviation limits about a polynomial regression curve

STRUCTURAL MATERIALS FOR SUPERCONDUCTING MAGNETS

MATERIAL AISI 304 (N, LN, HN, LPN) STAINLESS STEEL (ANNEALED)	PROPERTY TENSILE YIELD STRENGTH



TENSILE YIELD STRENGTH VS. TEMPERATURE

The scatter band represents two standard deviations about a linear regression curve based upon the available data (273 measurements). See Page 19 for the equation used to generate the curve, and for tabulated values. Because of the strong dependence of the low-temperature yield strength upon nitrogen content, and the wide range of nitrogen content (0.09 wt.% $\leq$ [N] $\leq$ 0.26 wt. %) in the set of measurements on which the curve is based, some of the 4-K and 77-K measurements fall outside the band. Therefore, this curve indicates only the general trend of yield strength vs. temperature, and Pages 2.0-2.7 and the Supporting Documentation Pages should be consulted for more detailed information on yield strength as a function of [N], [C], and temperature.

STRUCTURAL MATERIALS FOR SUPERCONDUCTING MAGNETS

MATERIAL AISI 304 (N, LN, HN, LHN) STAINLESS STEEL (ANNEALED)	PROPERTY TENSILE YIELD STRENGTH

TENSILE YIELD STRENGTH

Temp., K	MPa	(ksi)
4	810	(118.)
20	782	(113.)
40	746	(108.)
60	711	(103.)
77	681	(98.8)
80	676	(98.0)
100	640	(92.8)
120	606	(87.7)
140	569	(82.5)
160	534	(77.4)
180	498	(72.2)
200	463	(67.1)
220	427	(62.0)
240	392	(56.8)
260	356	(51.7)
273	333	(48.3)
280	321	(46.5)
300	285	(41.4)

TENSILE YIELD STRENGTH DATA

Test Temp., K	Number of Data Points
4	50
20	1
77	40
111	1
137	1
193/195	9
200	4
223	1
293/300	166

Total number of data points: 273

YIELD STRENGTH (MPa) = $b_0 + b_1 T$

$4 \text{ K} \leq T \leq 300 \text{ K}$

(S.D. = 86 MPa)

COEFFICIENTS:

$b_0 = 8.175 \times 10^2$

$b_1 = 1.774$

From: SSCVX1::ZBASNIK 10-JUN-1990 20:17:30.30
To: FNAL::JBS
CC:
Subj: shell material

Jim-
Been thinking and reading about the shell material. Going to the austenitic stainless steels is in the right direction. I would consider three candidates:

304N
304LN
316LN

The expected yield stresses of these are:

	R.T. Yield, ksi	4 K Yield, ksi
304N	47	124
304LN	44	117
316LN	50	143

I would imagine that all of these are saisfactory from a R.T. stress viewpoint.

The latest thinking in welding these materials for cryogenic applications is to use the low carbon grades, since these are less prone to carbide precipitation at the grain boundaries. Therefore, I would propose either the 304LN or the 316LN materials. 316LN is the more expensive, by about 30% or so.

The filler metal to use in welding is a ER316L, which has a R.T. yield stress ofabout 50 ksi, so it matches the base metal quite well. The rub comes in at low temperature, where the yield stress is only about 100 ksi.The concern is according to Jay, that the thermal contraction mismatch between the yokes and the end plate causes a large bending stress in the tube. We therefore want to have as high a yield stress material as possible, so it would seem that 316LN drops out as the best material. However, since we seem to be limited by the yield stress in the weld metal, we may be spending money needlessly for the more expensive 316LN, since the weld filler metal is the limitation.

Dick Reed has been "incommunicado" since he's been on vacation. I'll try to get in touch with him on Monday to see if he agress with all this. I do know that he felt that we have to have some fairly tight composition specs for the production models to ensure long term reliability.

See you on Monday evening.

Jon Z