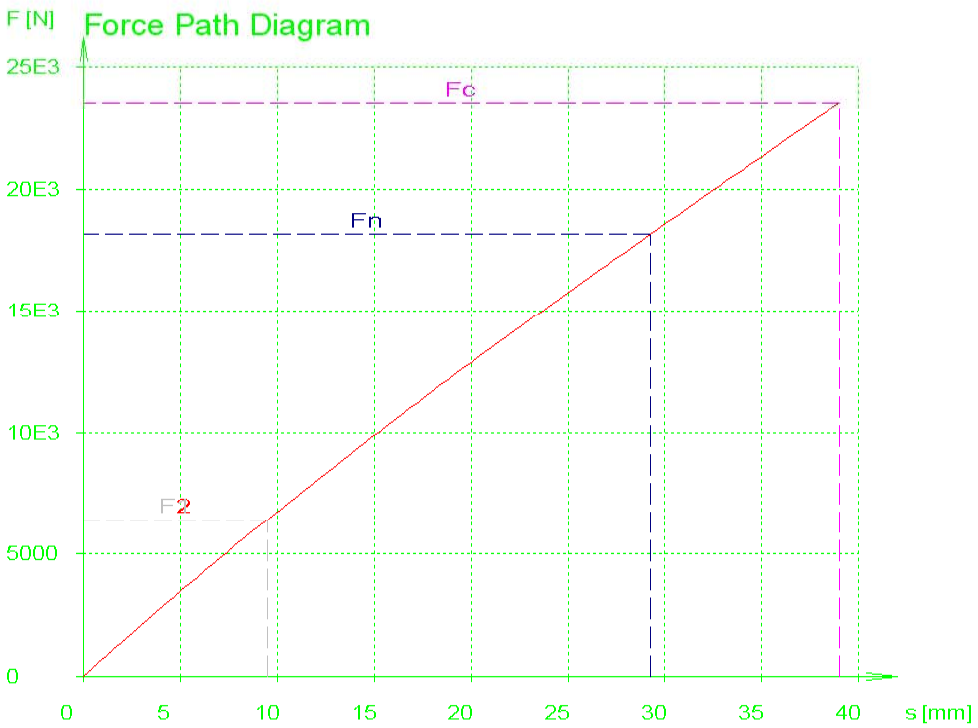
OH Coil Pre Load System
TF hot OH cold

Calculations for the least critical system scenario.
From Pre Load of 17.87 mm
8.4 mm of compression are released due to the
TF coil thermal expansion = 8.4 mm
Therefore, the total compression on the
Spring stack is = 9.47 mm

For a single spring s = .364 mm
For the stack = .3642 x 26 = 9.47 mm
Maximum obtained force on the OH coil
With 14 stacks = 6,407. x 14 = 89,698 N
(20,157. lbs.)

FED4 - Disk Spring Calculation - 14 Stacks TF Hot Oh Cold 2 26 Sp.fd4

File Edit View CAD Database Document OLE Help



Di = 30.5 mm
De = 60 mm
t = 3.5 mm
L0 = 5 mm

nf = 1
np = 26
Lc = 91 mm
L0 = 130 mm

Stainless Steel Required

E = 206000 MPa
mue = 0.3
rho= 7.85 kg/dm^3
sigma perm = 1230 MPa
(DIN 2092)

	0	1	2	n	c	
s	0.00	9.47	9.47	29.25	39.00	mm
L	130.00	120.53	120.53	100.75	91.00	mm
F	0	6411	6411	18153	23528	N
R	18566	16723	16723	14515	14245	N/mm
sigma I	0	-850	-850	-2434	-3121	MPa
sigma III	0	459	459	1297	1650	MPa
si	0.00	0.36	0.36	1.13	1.50	mm
Li	5.00	4.64	4.64	5.00	0.00	mm
Fi	0	6411	6411	18153	23528	N

messages

- none -

Pre Load was = 17.87 mm
-TF hot = 8.4 mm
Total compression = 9.47 mm
Total Force/Stack = 6,411. N
(1,441. lbs.)
Constant Force on OH coil
(1,441 x 14 = 20,169. lbs)

10/14/2010 11:08 - HEXAGON FED4 V5.1 #0175 - Princeton Plasma Physics Lab - C:\hexagon\FED4\14 Stacks TF Hot Oh Cold 2 26 Sp.fd4

start TFhotOHcold26_14.p... FED4 - Disk Spring C... 11:09 AM

FED4 - Disk Spring Calculation - 14 Stacks TF Hot Oh Cold 2 26 Sp.fd4

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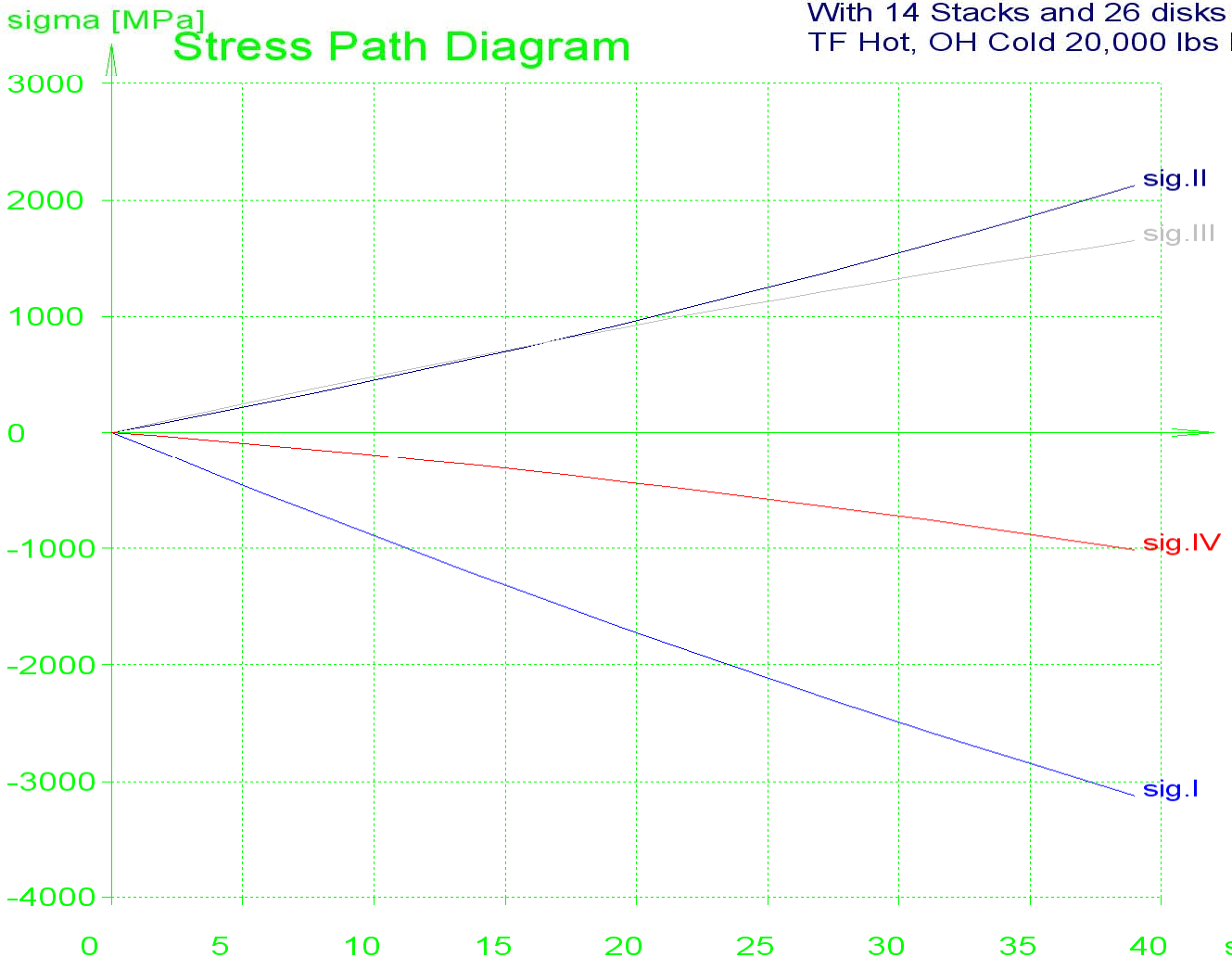
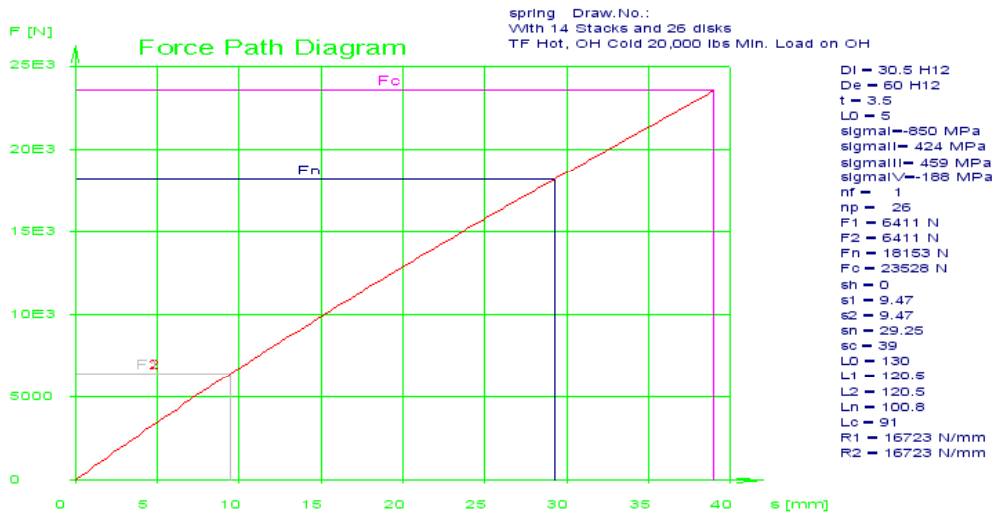
spring Draw.No.:
With 14 Stacks and 26 disks
TF Hot, OH Cold 20,000 lbs Min. Load on OH



Di = 30.5 H12
De = 60 H12
t = 3.5
L0 = 5
sigmaI=-850 MPa
sigmaII= 424 MPa
sigmaIII= 459 MPa
sigmaIV=-188 MPa
nf = 1
np = 26
F1 = 6411 N
F2 = 6411 N
Fn = 18153 N
Fc = 23528 N
sh = 0
s1 = 9.47
s2 = 9.47
sn = 29.25
sc = 39
L0 = 130
L1 = 120.5
L2 = 120.5
Ln = 100.8
Lc = 91
R1 = 16723 N/mm
R2 = 16723 N/mm

10/14/2010 11:32 - HEXAGON FED4 V5.1 #0175 - Princeton Plasma Physics Lab - C:\hexagon\FED4\14 Stacks TF Hot Oh Cold 2 26 Sp.fd4

start TfhotOHcold26_14.p... FED4 - Disk Spring C... 11:33 AM



spring Draw.No.:
With 14 Stacks and 26 disks
TF Hot, OH Cold 20,000 lbs Min. Load on OH

Di = 30.5 H12
De = 60 H12
t = 3.5
L0 = 5
sigmaI=-850 MPa
sigmaII= 424 MPa
sigmaIII= 459 MPa
sigmaIV=-188 MPa
nf = 1
np = 26
F1 = 6411 N
F2 = 6411 N
Fn = 18153 N
Fc = 23528 N
sh = 0
s1 = 9.47
s2 = 9.47
sn = 29.25
sc = 39
L0 = 130
L1 = 120.5
L2 = 120.5
Ln = 100.8
Lc = 91
R1 = 16723 N/mm
R2 = 16723 N/mm

spring Draw.No.:
With 14 Stacks and 26 disks
TF Hot, OH Cold 20,000 lbs Min. Load on OH

SINGLE DISK SPRING			
inside diameter	Di	mm	30.5 H12
outside diameter	De	mm	60 H12
thickness	t	mm	3.5
length	L0	mm	5
weight	m	g	57.61
usable spring travel sn=0.75*h0	sin	mm	1.125
max. spring travel h0=sc	sic	mm	1.5
spring force with sn=0.75*sc	Fin	N	18153
No. of springs per package	nf		1
No. of spring packages	np		26

Length mm	Sp.travel mm	Load N	Sigma MPa
L0 = 130.00			
L1 = 120.53	s1 = 9.47	F1 = 6411.21	sigma1 = 459
	sh = 0.00	Fh = 0.00	sigmah = 0
L2 = 120.53	s2 = 9.47	F2 = 6411.21	sigma2 = 459
Ln = 100.75	sn = 29.25	Fn = 18152.58	sigman = 1297
Lc = 91.00	sc = 39.00	Fc = 23528.21	sigmac = 1650

Cond.	Modification	Date	Name

	Date	Name
Compl.	08/25/2010	P. Rogoff
Check		
Stand.		

Princeton Plasma Physics Lab

Disk Spring

Page
Pg.

C:\hexagon\FED4\14 Stacks TF Hot Oh Cold 2 26 Sp.fd4

10/14/2010 11:38

FED4 - Disk Spring Calculation - 14 Stacks TF Hot Oh Cold 2 26 Sp.fd4

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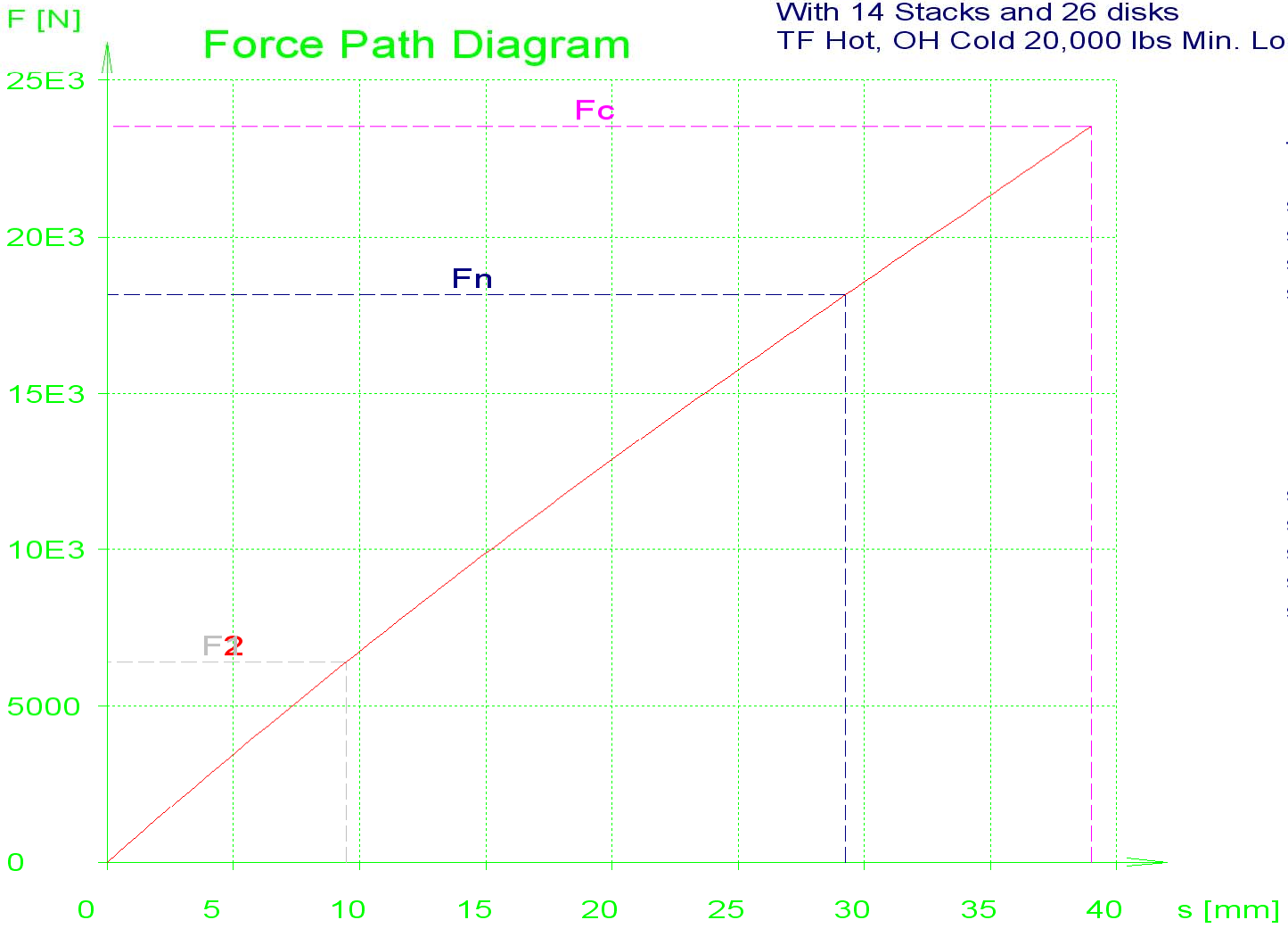
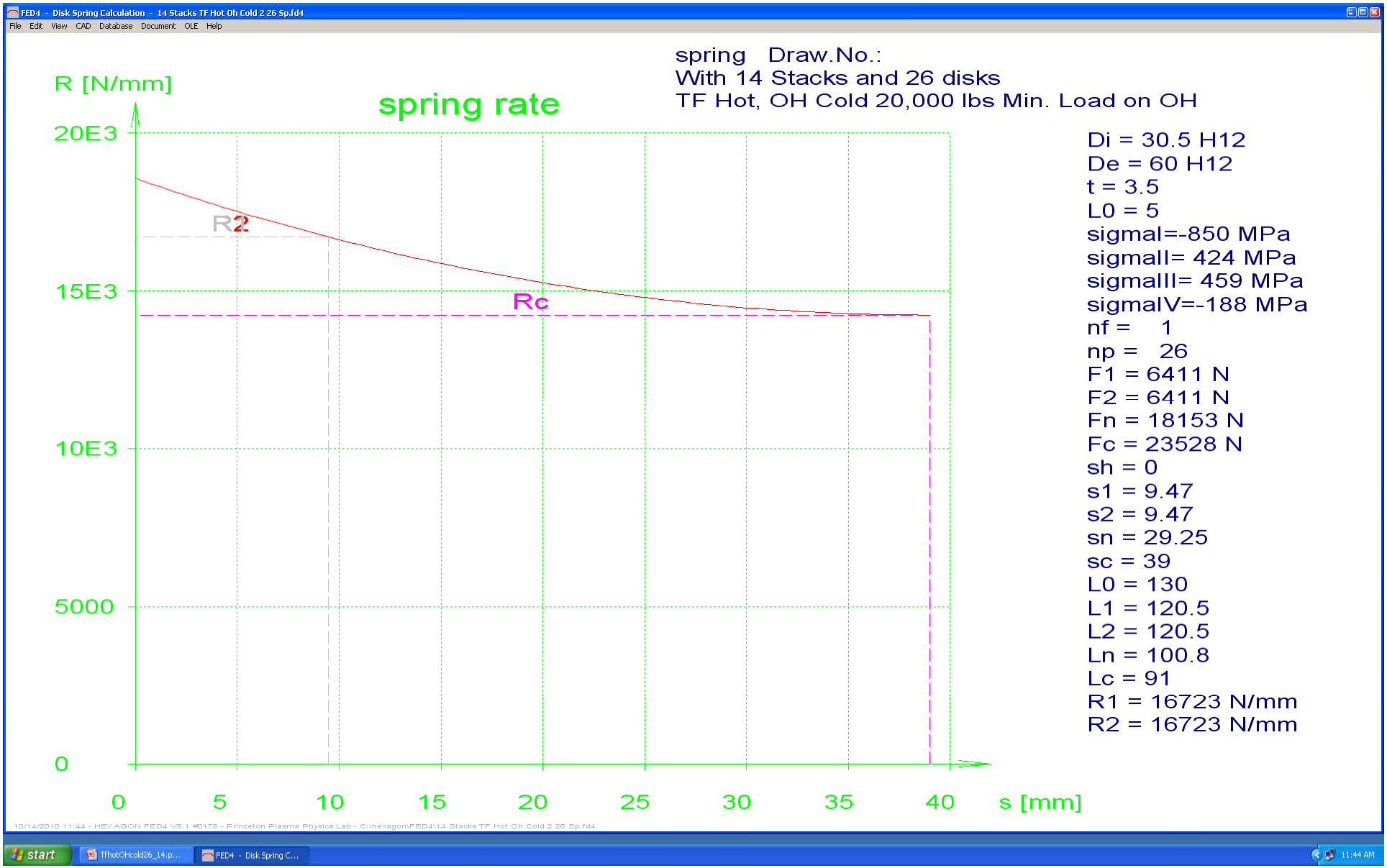
spring Draw.No.:
With 14 Stacks and 26 disks
TF Hot, OH Cold 20,000 lbs Min. Load on OH

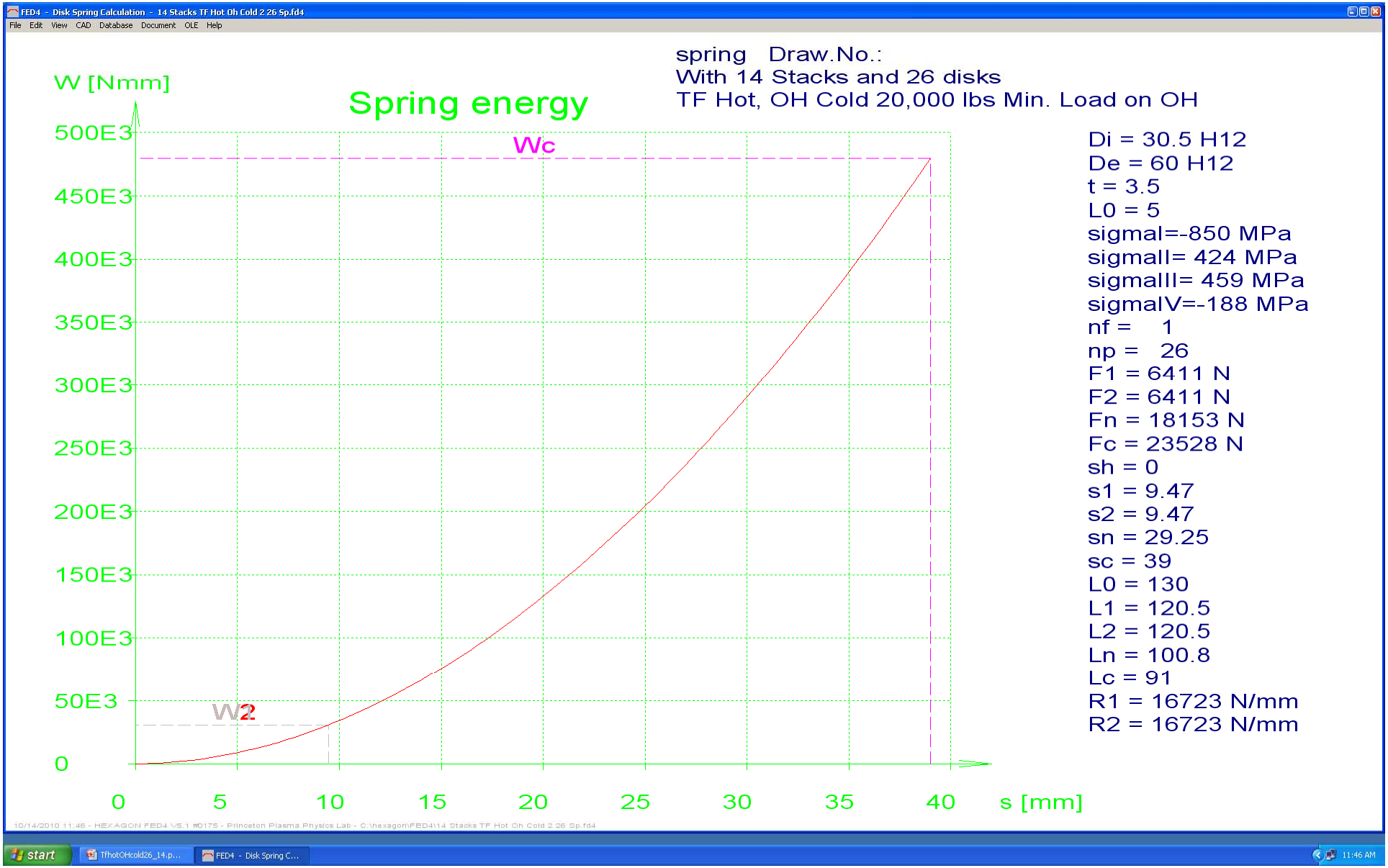


Di = 30.5 H12
De = 60 H12
t = 3.5
L0 = 5
sigmaI=-850 MPa
sigmaII= 424 MPa
sigmaIII= 459 MPa
sigmaIV=-188 MPa
nf = 1
np = 26
F1 = 6411 N
F2 = 6411 N
Fn = 18153 N
Fc = 23528 N
sh = 0
s1 = 9.47
s2 = 9.47
sn = 29.25
sc = 39
L0 = 130
L1 = 120.5
L2 = 120.5
Ln = 100.8
Lc = 91
R1 = 16723 N/mm
R2 = 16723 N/mm

10/14/2010 11:42 - HEXAGON FED4 V5.1 #0175 - Princeton Plasma Physics Lab - C:\hexagon\FED4\14 Stacks TF Hot Oh Cold 2 26 Sp.fd4

start TfhotOHcold26_14.p... FED4 - Disk Spring C... 11:42 AM

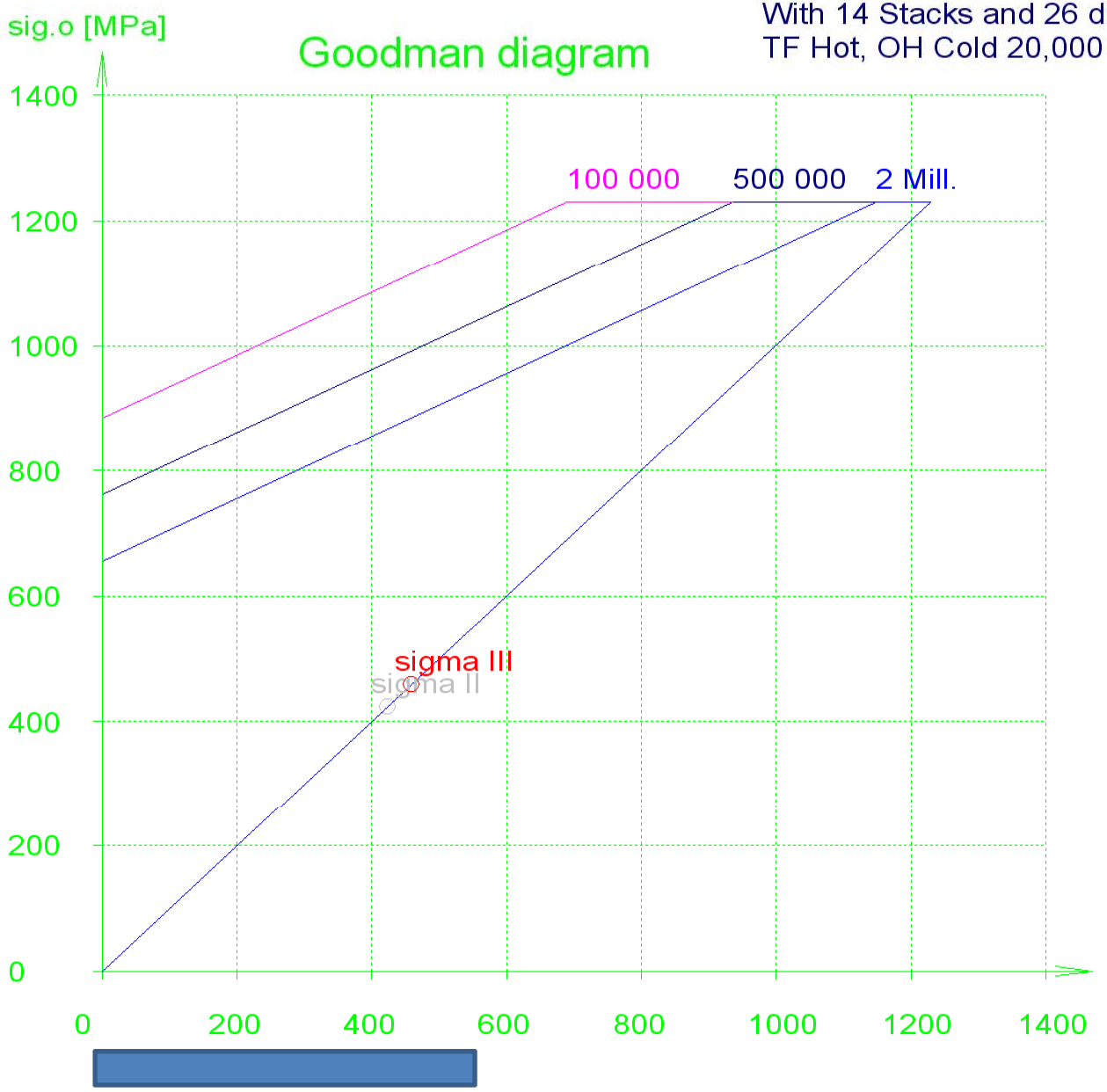

FED4 - Disk Spring Calculation - 14 Stacks TF Hot Oh Cold 2 26 Sp.fd4
File Edit View CAD Database Document OLE Help
spring Draw.No.:
With 14 Stacks and 26 disks
TF Hot, OH Cold 20,000 lbs Min. Load on OH
R [N/mm]
spring rate
20E3
15E3
10E3
5000
0
R2
Rc
0 5 10 15 20 25 30 35 40
s [mm]
Di = 30.5 H12
De = 60 H12
t = 3.5
L0 = 5
sigmaI=-850 MPa
sigmaII= 424 MPa
sigmaIII= 459 MPa
sigmaIV=-188 MPa
nf = 1
np = 26
F1 = 6411 N
F2 = 6411 N
Fn = 18153 N
Fc = 23528 N
sh = 0
s1 = 9.47
s2 = 9.47
sn = 29.25
sc = 39
L0 = 130
L1 = 120.5
L2 = 120.5
Ln = 100.8
Lc = 91
R1 = 16723 N/mm
R2 = 16723 N/mm
10/14/2010 11:44 - HEXAGON FED4 V5.1 #0175 - Princeton Plasma Physics Lab - C:\hexagon\FED4\14 Stacks TF Hot Oh Cold 2 26 Sp.fd4
start
TfhotOHcold26_14.p...
FED4 - Disk Spring C...
11:44 AM


FED4 - Disk Spring Calculation - 14 Stacks TF Hot Oh Cold 2 26 Sp.fd4
File Edit View CAD Database Document OLE Help
spring Draw.No.:
With 14 Stacks and 26 disks
TF Hot, OH Cold 20,000 lbs Min. Load on OH
W [Nmm]
Spring energy
Wc
W2
500E3
450E3
400E3
350E3
300E3
250E3
200E3
150E3
100E3
50E3
0
0
5
10
15
20
25
30
35
40
s [mm]
Di = 30.5 H12
De = 60 H12
t = 3.5
L0 = 5
sigmaI=-850 MPa
sigmaII= 424 MPa
sigmaIII= 459 MPa
sigmaIV=-188 MPa
nf = 1
np = 26
F1 = 6411 N
F2 = 6411 N
Fn = 18153 N
Fc = 23528 N
sh = 0
s1 = 9.47
s2 = 9.47
sn = 29.25
sc = 39
L0 = 130
L1 = 120.5
L2 = 120.5
Ln = 100.8
Lc = 91
R1 = 16723 N/mm
R2 = 16723 N/mm
10/14/2010 11:46 - HEXAGON FED4 V5.1 #0175 - Princeton Plasma Physics Lab - C:\hexagon\FED4\14 Stacks TF Hot Oh Cold 2 26 Sp.fd4
start
TfhotOHcold26_14.p...
FED4 - Disk Spring C...
11:46 AM

FED4 - Disk Spring Calculation - 14 Stacks TF Hot Oh Cold 2 26 Sp.fd4

File Edit View CAD Database Document OLE Help

spring Draw.No.:
With 14 Stacks and 26 disks
TF Hot, OH Cold 20,000 lbs Min. Load on OH



Di = 30.5 H12
De = 60 H12
t = 3.5
L0 = 5
sigmaI=-850 MPa
sigmaII= 424 MPa
sigmaIII= 459 MPa
sigmaIV=-188 MPa
nf = 1
np = 26
F1 = 6411 N
F2 = 6411 N
Fn = 18153 N
Fc = 23528 N
sh = 0
s1 = 9.47
s2 = 9.47
sn = 29.25
sc = 39
L0 = 130
L1 = 120.5
L2 = 120.5
Ln = 100.8
Lc = 91
R1 = 16723 N/mm
R2 = 16723 N/mm

10/14/2010 11:47 - HEXAGON FED4 V5.1 #0175 - Princeton Plasma Physics Lab - C:\hexagon\FED4\14 Stacks TF Hot Oh Cold 2 26 Sp.fd4

start TfhotOHcold26_14.p... FED4 - Disk Spring C... 11:47 AM

FED4 - Disk Spring Calculation - 14 Stacks TF Hot Oh Cold 2 26 Sp.fd4

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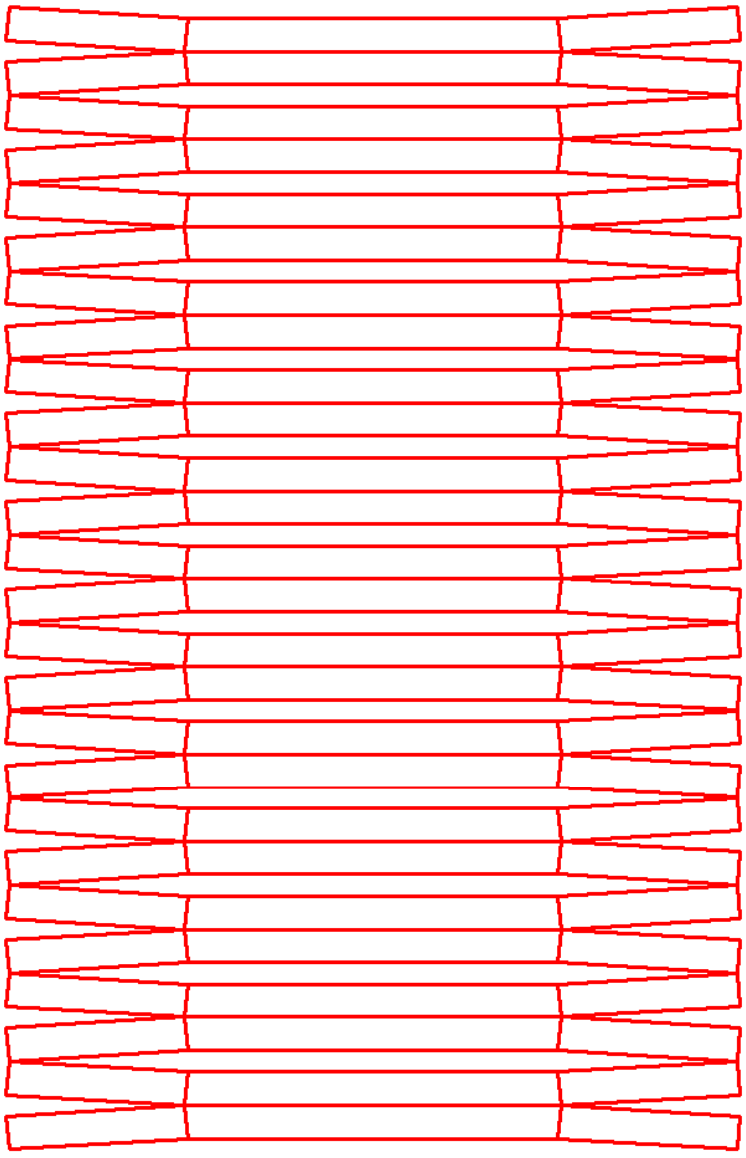
Complete Stack 26 springs



	A	B	C	D
1				
2		Calculations in (N and mm) units		
3				
4		Calcs Based on the SCHNORR data formulas.		
5				
6		Note: These calculations are for SCHNORR #15900 as basic shape		
7				
8				
9		De - Ouside diameter	60	mm
10		Di - Inside diameter	30.5	mm
11				
12		pi	3.14	
13		1/pi	0.3185	
14		3/pi	0.9554	
15		6/pi	1.9108	
16				
17		del=De/Di Schnorr Formula #2	1.9672	
18				
19		Indel=ln(De/Di)	0.6766	
20				
21		del-1	0.9672	
22		del+1	2.9672	
23				
24				
25				
26		(del-1/del)^2	0.2417	
27		(del+1)/(del-1)	3.0678	
28		(2/Indel)	2.9559	
29				
30				
31		K1 =1/pi(((del-1/del)^2))/((del+1)/((del-1)-(2/Indel))) Formula #3	0.6879	
32				
33		K2=6/pi(((del-1)/(Indel))-1)))/(Indel) Formula #4	1.2129	
34				
35		K3=3/pi(del-1/Indel) Formula #5	1.3657	
36				
37		K4=1 since thikness is less than 6 mm Formula #6 (see chapter	1	
38				
39				
40		FORCE and STRESS Calculations		
41				
42				
43				
44		lo= total height	5.004	mm
45		ho= lo-t	1.499	mm
46		t=average spring thickness	3.505	mm

Calculations based on SCHNORR catalogue equations for a single disk at constant compression
s = .364 mm

Stack compression in this case:
s = 9.47 mm.

Or (.364 x 26) =
9.47 mm.
Force =6,428. N
("HEXAGON" F=6,411 N)

See slide #2

47		s= deflection of the single spring (from 75% of ho))	0.364	mm
48		E= modulus for steel	206000	N/mm^2
49		mu= Poisson's ratio	0.3	
50		1-mu^2	0.91	
51		4E/(1-mu^2)	905494.505	
52		t^4/(K1*de^2)	0.06094519	
53		s/t	0.10385164	
54		ho/t	0.42767475	
55		s/2t	0.05192582	
56				
57		Formula #8a	6428.45	N
58				
59		Formula #9 Stresses at the center of rotation (point OM)	-445.71	N/mm^2
60		(should be less then -1600N/mm^2)		
61		t^2/(K1*de^2)	0.00496093	
62				
63		formula #10 Stress at point (I)	-849.75	N/mm^2
64				
65				
66		formula #11 Stress at point (II)	424.527204	N/mm^2
67				
68				
69		formula #12 Stress at point (III)	459.19	N/mm^2
70				
71		1/del	0.50833333	
72		(K2-2K3)	-1.5185995	
73		(ho/t-s/2t)	0.37574893	
74				
75		Formula #13 Stress at point (IV)	-188.56	N/mm^2
76				
77		t^3/(K1*de^2)	0.01738807	
78				
79		Formula #14 Spring Rate (dF/ds)	16781.43	N/mm
80				
81		Formula #15 Spring Work (Integral from 0 to s, of F*ds)	1190.33	N-mm
82				
83		2E/(1-mu^2)	452747.253	
84		t^5/(K1*de^2)	0.2136129	
85				
86		**Basic requirements for a good Disk spring design**		
87		**For the above basic equations to work**		
88				
89		This Spring is linear because ho/t=.428 (since for ho/t<0.4 are li	slightly non-LINEAR	
90				
91		del=De/Di=2.3923 and it should be between 1.75 and 2.5	O.K.	
92		Outside diameter De, Inside diameter Di		

93			
94	ho/t=(lo-t)/t=.428 and it should be between 0.4 to 1.3	O.K.	
95	ho=lo-t cone height, t=disk thickness		
96			
97	De/t=17.12 and it should be between 16. and 40.	O.K.	
98			
99	**Conclusion: This spring under the constant load of 3790.0 N is O.K.**		
100			
101			
102	Basic machine operation requirements:		
103	1) TF coil inner leg maximum thermal expansion was calculated at 8.4mm		
104	2) OH coil requires a preload of 20,000.0 lbs total or 7,413.3 N (12 St) per stack. Must		
105	calculate the required deflection (s) for the preload force?		
106	3) OH coil thermal expansion was calculated at 6.0mm		
107			
108	So, the total each spring stack travel is = 8.4+6.0+calculated from minimum preload		
109			
110	For Fatigue predictions, using fatigue life diagrams for disk springs, one requires		
111	the Pre and Maximum loads stresses at points II or III (depending on del and ho/t)		
112			
113			
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