TITLE: - **SPRING STEEL WIRE FLEXURE POINT**
- based on calculation / equations used by CAC on 27 JAN 2004, see picture 1
WHO: - CIT, NAR, CAC, JHR, MPL
LIGO DCC NUMBER: - **D040183** **-04** DATE: - 29th April 2004

SECTION I **SUMMARY OF USE WITH THE STAGES IN A CPTYPE QUADRUPLE PENDULUM**

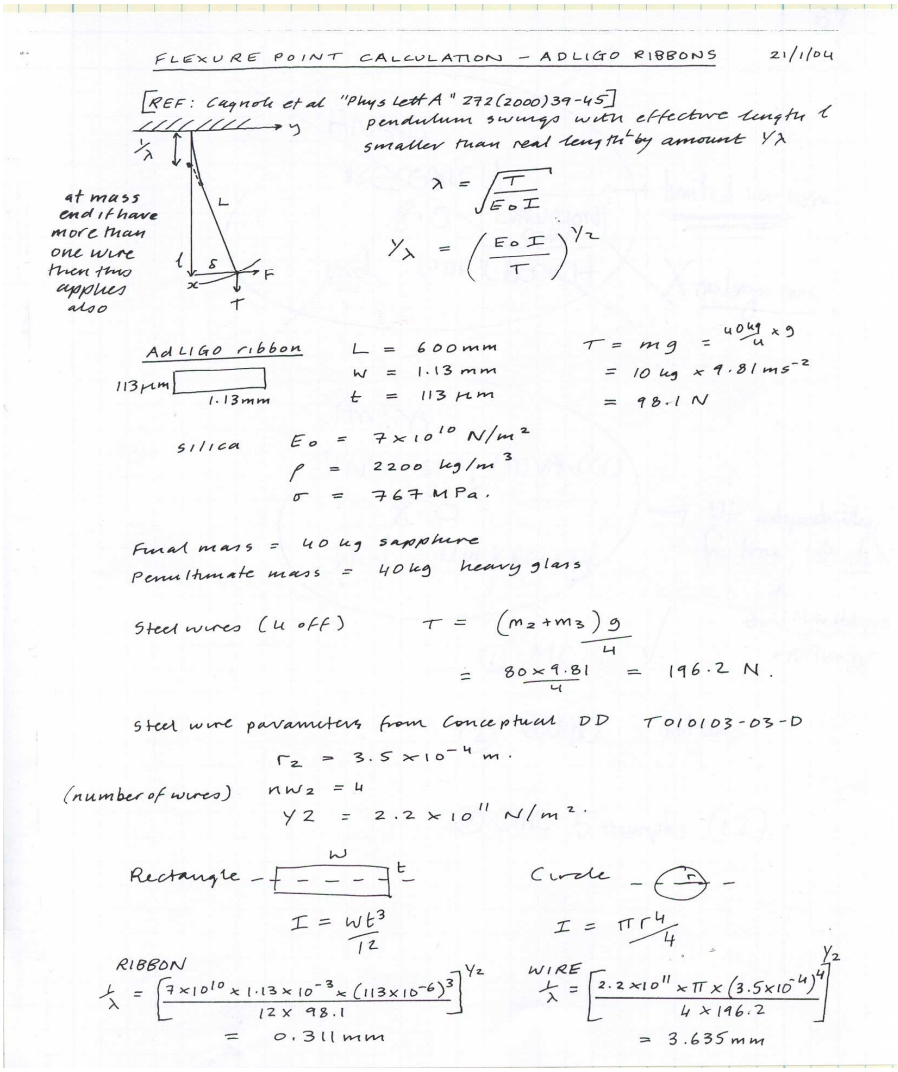
NOTE: - Using the radii supplied by NAR on Mon 09 FEB 2004 The following calculations should be edited for actual radii of wires

	Mass, (kg)	
Top Mass	22	
Upper Intermediate Mass	22	
Penultimate Mass	38.4	(previously 40kg, see numbers for flexure point that are scored out)
Test Mass	39.6	(previously 40kg, see numbers for flexure point that are scored out)

		FLEXURE POINT, all in mm		
A. CALCULATION OF FLEXURE POINT USING THE WIRE RADIUS FROM THE MATLAB MODEL			with masses 38.4 and 39.6 kg	
Top Wire	5.50E-04	~~4.9~~	5.14	
Upper Int Wire	3.50E-04	~~3.2~~	3.25	
Penultimate Wire	3.10E-04	~~2.85~~	2.89	
Test Mass Wire	2.20E-04	~~2.03~~	2.04	(2.07 with test mass = 38.4 kg)

B. CALCULATION OF THE FLEXURE POINT USING THE ACTUAL WIRE RADIUS, SEE SECTION III.			with masses 38.4 and 39.6 kg	
Top Wire	546	~~5.02~~	5.07	
Upper Int Wire	355	~~3.3~~	3.35	
Penultimate Wire	317	~~2.98~~	3.02	
Test Mass Wire	228	~~2.18~~	2.19	(2.23 with test mass = 38.4 kg)

PICTURE (1): - FLEXURE POINT CALCULATION BY CARLOINE CANTLEY



SECTION II **USING THE CALCULATOR**

KEY: - INPUT / OUTPUT / CALCs.

1. QUAD TOP WIRE 22, 22, 40, 40 kg

radius	**5.46E-04** m			0.55 mm		
diameter	1.09E-03 m			1.09 mm		
mass	122 kg		Tension, T	598.41 kg*m/s^2		
no of wires	**2**		arera moment	6.98008E-14		
Youngs Modulus	**2.20E+11** Pa		lamda =	0.005065731 m	**Flexure Point =**	**5.07** mm

2. QUAD CP UPPER INT WIRE 22, 22, 40, 40 kg

radius	**3.55E-04** m			0.36 mm		
diameter	7.10E-04 m			0.71 mm		
mass	100 kg		Tension, T	245.25		
no of wires	**4**		arera moment	1.24739E-14		
Youngs Modulus	**2.20E+11**		lamda	0.003345095 m	**Flexure Point =**	**3.35** mm

3. QUAD CP PENULTIMATE WIRE 22, 22, 40, 40 kg

radius	**3.17E-04** m			0.32 mm		
diameter	6.34E-04 m			0.63 mm		
mass	78 kg		Tension, T	191.295		
no of wires	**4**		arera moment	7.93098E-15		
Youngs Modulus	**2.20E+11**		lamda	0.003020112 m	**Flexure Point =**	**3.02** mm

4. QUAD CP FINAL WIRE 22, 22, 40, 40 kg

radius	**2.28E-04** m			0.23 mm		
diameter	4.56E-04 m			0.46 mm		
mass	39.6 kg		Tension, T	97.119		
no of wires	**4**		arera moment	2.12241E-15		
Youngs Modulus	**2.20E+11**	*	lamda	0.00219 m	**Flexure Point =**	**2.19** mm

*** check?**

SECTION III: - **ACTUAL DIAMETERS OF WIRE**

MUSIC WIRE AVALIABLE FROM CALIFORNIA FINE WIRE COMPANY
http://www.calfinewire.com/

NOTE: - GEO 600 wire bought from
http://www.knight-group.co.uk/

	DIAMETER of Wire ENGLISH (thou)	RADIUS of Wire METRIC (microns)		WIRE RADIUS FROM NAR MODEL
6thou diam	6	76.2		
8thou diam	8	101.6		
10thou diam	10	127		
	12	152.4		
	14	177.8		
	16	203.2		
	17	215.9		
	18	228.6		220
	20	254		
	22	279.4		
	24	304.8		
	25	317.5		310
	26	330.2		
	27	342.9		
	28	355.6		350
	29	368.3		
	30	381		
	31	393.7		
	32	406.4		
	33	419.1		
	34	431.8		
	37	469.9		
	38	482.6		
	39	495.3		
	40	508		
	41	520.7		
	42	533.4		
	43	546.1		540

SECTION IV: - **OTHER EXAMPLES** FOR INTEREST ONLY

5 MODE CLEANER INTERMEDIATE WIRE, 3, 3, 3 kg

radius	**1.00E-04**	m		0.10	mm		
diameter	**2.00E-04**	m		0.20	mm		
mass	**6**	kg					
no of wires	**4**						
t	14.715						
Youngs Modulus	**2.20E+11**		*	lamda	0.001084	m	
arera moment	7.85398E-17			Flexure Point =			**1.08** mm
						NOT INCLUDED!	

6 MODE CLEANER UPPER WIRE, 3, 3, 3 kg

radius	**1.80E-04**	m		0.18	mm		
diameter	**3.60E-04**	m		0.36	mm		
mass	**9**	kg					
no of wires	**2**						
t	44.145						
Youngs Modulus	**2.20E+11**		*	lamda	0.002027	m	
arera moment	8.2448E-16			Flexure Point =			**2.03** mm
						NOT INCLUDED!	

7 GEO 600, UPPER WIRE 4.5, 4.5, 4.5 kg

radius	**2.50E-04**	m		0.25	mm		
diameter	**5.00E-04**	m		0.50	mm		
mass	**18**	kg					
no of wires	**2**						
t	88.29						
Youngs Modulus	**2.20E+11**		*	lamda	0.002765	m	
arera moment	3.06796E-15			Flexure Point =			**2.76** mm
						NOT INCLUDED!	

8 MC LOWER WIRE

diameter	1.50E-04				
mass	3	lamda	0.000862013	m	
t	7.36E+00		**0.86**	mm	
area moment	2.48505E-17				

THE FOLLOWING ASSUMPTION NEED TO BE CHECKED!

SECTION V: - **CONCLUSIONS / PARAMETERS FOR CP Type QUAD**

1 FLEXURE POINTS

Top wire at Top blades	5	mm
Top wire at Top mass	5	mm
Upper Intermediater wire at top mass	3.3	mm
Upper intermediate wire at upper intermediate mass	3.3	mm
Penultimate wiree at upper intermediate mass	3	mm
Penultimate wire at penultime mass	3	mm
Test mass wire at Penultimate mass	2	mm
Test mass wire at test mass	2	mm

NB: FLEXURE POINT CHANGE FROM 39.6 kg to 38.4 kg for reaction chain final stage is small and therefore design left at 2mm

2 MASS

Top mass	22	kg
Upper Intermediate Mas	22	kg
Penultimate Mass	38.4	kg
Test Mass	39.6	kg

3 WIRE

Top Wire	18	thou diameter
Upper Intermediate Wire	25	thou diameter
Penultimate Wire	28	thou diameter
Final Wire	43	thou diameter

TITLE Pitch adjustment of the ALIGO - MC test mass by adjustment carried out at the top mass
NAMES Calum I. Torrie Norna Robertson, Mike Perreur Lloyd, Alastair Grant
DATE June 19th 2004
LIGO-DCC D040183-04 page 2
OFFSET Cylinder ~ 1 inch diameter 50mm long with or without a set screw insert, LIGO-D020137 50 mm (long)
DISTANCE Experiment carried out at 10ft from the optic, distance = 3.048 m (10 ft)

MASS OFFSETS

Number	*Name*	*mass of offset*	*mass of combination*
1 # 7/8-9	SET SCREW	120 g	256g
2 #1/2-20	SET SCREW	40 g	266g
3 #1/2-13	SET SCREW	39 g	270g
4 -	SOLID ROD	270 g	270g

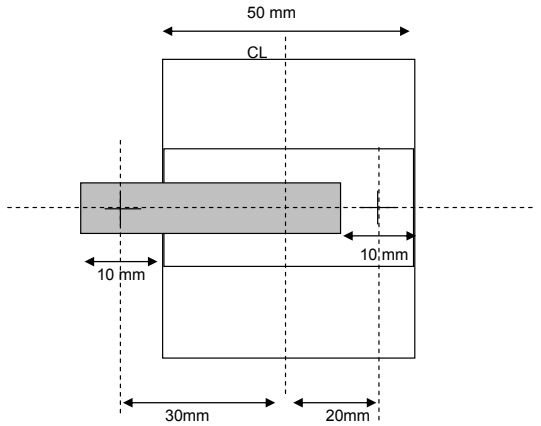
NOTE: - 1.3 with original d's
0..87 with new d's including flexure points

movement of offset	2x vertical distance, Z	Vertical distance, Z	alpha	equiv moving mass	average leverarm	Torque		Theory Torque	
mm	*mm*	*mm*	*mrad*	*g*	*mm*	*Nm*		*Nm*	
1	**#7/8-9**	120 g							
20	95	47.5	15.6	48	25	1.18E-02		1.79E-02	
10	45	22.5	7.4	24	25	5.89E-03		8.48E-03	
0	0	0	0.0	-	-				
-10	-45	-22.5	-7.4	24	25	-5.89E-03		-8.48E-03	
-20	-85	-42.5	-13.9	48	25	-1.18E-02		-1.60E-02	
2	**# 1/2-20**	40 g							
20	30	15	4.9	16	25	3.92E-03		5.66E-03	
10	15	7.5	2.5	8	25	1.96E-03		2.83E-03	
0	0	0	0.0	-	-	-			
-10	-15	-7.5	-2.5	8	25	-1.96E-03		-2.83E-03	
-20	-30	-15	-4.9	16	25	-3.92E-03		-5.66E-03	
3	**#1/2-13**	39 g							
20	30	15	4.9	15.6	25	3.83E-03		5.66E-03	
FROM NAR EMAIL 10	15	7.5	2.5	7.8	25	1.91E-03		2.83E-03	**
0	0	0	0.0	-	-	-			
-10	-15	-7.5	-2.5	7.8	25	-1.91E-03		-2.83E-03	
-20	-30	-15	-4.9	15.6	25	-3.83E-03		-5.66E-03	
4	**SOLID ROD**	270 g							
10	100	50	16.4	54	25	1.32E-02		1.89E-02	
5	50	25	8.2	27	25	6.62E-03		9.43E-03	
0	0	0	0.0	-	-				
-5	-45	-22.5	-7.4	27	25	-6.62E-03		-8.48E-03	
-10	-100	-50	-16.4	54	25	-1.32E-02		-1.89E-02	

** EMAIL FROM NAR on 17 JUNE 2004
Xfer fn at DC: Test mass pitch/torque applied at top mass = **0.87** rad per Nm

Torque needed to pitch test mass 2.5mrad, torque = 0.002874 Nm
2.5 mrad
gravity = 9.81 m/s^2

Sketch explaining detail wrt leverarm and mass from email by NAR

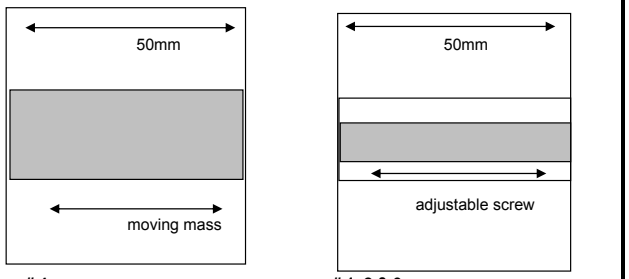


Compare this to 8gms at lever arm of 25 mm (corresponds to moving previously centred screw 50 mm long by 10 mm, so that at one end we gain 10 mm of rod at lever arm centred at 30mm and at other

end we "lose" 10mm of rod centred at 20 mm - thus equiv to gaining 20mm of rod, or 8 gms,
at an average lever arm of 25mm)

This gives torque of 0.008 x 9.8 x 0.025 = 1.96e-3 Nm

Below are two sketches of mass offsets, described above



 # 4 **# 1, 2 & 3**

MC FELXURE POINTS TOP 2mm
June 19th 2004, CIT MIDDLE 1mm
BOTTOM 0.8mm * can we do without?

EMAIL: - AG, NAR, MPL, CIT
NOTES
1 QUAD on hold for now
2 TIE up experiment with NAR (MATLAB) and AG EXCEL CALCULATOR
- use email from NAR
3 # from NAR for QUAD