**Mechanical limits of 48"dome drive/bogie system**

Machine generated alternative text:
DOME DRIVESPANG 
semg 

From dwg 102165 & 102166

**Calculate Preload Spring rate:**

Karl D reports that installed spring compressed length is 11.5". This is longer than shown in assembly dwg. (9.375")

Spring coil and wire diameter measure, # of coils counted. Confirmed spring is according to drawing.

**Determine spring rate**

Using calculator and assuming closed ground end………10 active coils.

<http://www.acxesspring.com/spring-calculator.html>

Machine generated alternative text:
Custom Part Number 
Custom Part Number 
Rates & Loads 
Spring Rate (or Spring constant), k 
True Maximum Load, True : 
Maximum Load Considering Solid Height, 
Solid Height - 
Safe Travel 
True Maximum Travel, True Travelm„ 
Maximum Travel Considering Solid Height, 
Solid Height : 
Minimum Loaded Height 
PC750-5250-12.ooo- 
MW-13.250-CG-N-lN 
498.827 Lbs/ln 
1,963.113 lbF 
1,963.113 lbF 
3.935 In 
3.935 In 
9.315 In 
Physical Dimensions 
Diameter of spring wire, d: 
Outer diameter of spring, Dourer : 
Inner diameter of spring, 
Mean diameter of spring, 
Free length of spring; 
Number of active coils; na : 
Number of total coils, nT_ 
0.750 In 
5.250 In 
3.750 In 
4.500 In 
13.250 In 

**Currently installed preload on tire**

Based on measured compressed length of 11.5" (from Karl D), and spring rate from above calculator: k= spring rate = 500 lbs/in

dL= compression from free length = 13.25 - 11.5=1.75"

Fs= Spring force= dL \* k = 1.75" \* 500lbs/in = 875 lbs

Ft = Load on tire from Spring force (current installed)

 Spring arm Lever ratio: 38/28

Fs \* 38" = Ft \* 28"

Ft = 875 \*38/28= 1187.5 lbs

**Nominal design preload on tire maximum over-hung load on speed reducer:**

Reducer manufacturers consider two factors: bearing life and shaft strength, and generally provide tables and/or formulas to calculate acceptable OHL from radial force and distance. Sumitomo quoted OHL for selected reducer configuration: 7550 lb at center of 3.54" shaft length; presumed de-rating to 4454 lb at 3" distance, or 2429 lb at 5.5".

As tire wears position of overhung load changes

Assuming conservative **5.5" overhung load rating of 2429 lbs**

Ft (28/38)= spring load = 2429\*(28/38) = 1789 lbs

This would correspond to 1790/500 = 3.58" spring compression

dL= compression from free length = 13.25 - 9.375 = 3.875 (nominal spring comp. from dwg)

**Dome drive calculations**

Friction drive wheel reference

<http://www.schwingmetall.com/download/catalog/WT5556_Rotafrix_Catalog_en.pdf>

Typical coefficient of friction for elastomeric/steel Friction Drive: 0.7

Friction load:

We measured 320 lb pull to move the dome (breakaway from static was the same, there is no indication of higher static friction). Assuming 10° pull misalignment in Y and Z, gives 310 lb tangential pull. With a 21 ft radius, dome rolling friction ≈ 6720 lb-ft.

Inertial Load:

From calculations using dome and motor properties: ~17500 lb-ft torque

(see 48in Dome Calculations doc)

This is worst case value based on theoretical motor output. A more realistic and lower value could be derived from actual dome acceleration measurements.

Max Total torque: Friction torque + Inertia torque: 6720 lb-ft + 17500 lb-ft = 24220 lb-ft

Tangential start-up force on dome drive band: 24220 lb-ft / 21ft = **1153 lbs**

**Theoretical traction drive force:**

Current Installed condition:

Drive wheel pre-load: 1187.5 lbs

Traction force with CoF: 1187.5 \* 0.7 = 831.25 lbs

Maximum design spring preload condition: (set by speed reducer overhung load)

Drive wheel pre-load: 2429 lbs

Traction force with CoF: 2429 \* 0.7 = **1700 lbs**

Based on this maximum required traction force, we should be able to drive at maximum acceleration of 1 deg/s/s.

**Dome truck radial bearing capacity**

Dome truck radial bearing: **MRC 5208**

Double row angular contact bearing

Assume worst case that 2 radial bearings are loaded:

Nominal spring preload design condition:

Drive wheel pre-load: 2429 lbs

Radial load per bearing: ~ 2429/2= 1214 lbs

Machine generated alternative text:
5200C bearings are used with moderate to 
heavy radial loads, two-directional thrust 
loads, or a combination of both. 
cz/SBa 
One seal 
CFG/SBKFG 
One shield 
and snap- ring 
CFF/SBKFF 
Two shields 
CZG 
One seal 
and snap-ring 
CZZ/SBKZZ 
Two seals 
CFFG/SBKFFG 
Two shields 
and snap- ring 
CFZ/SBKFZ 
Shield and seal 
CZZG 
Two seals 
and snap-ring 
Speed rating2) 
Open and shielded 
CF/SBKF 
One shield 
CG/SBKG 
Snap-ring 
Outside 
diameter 
300 
CFZG 
Shield, seal 
and snap-ring 
MRC 
bearing 
number 
5200SB 
5201SB 
5202SB 
5203SB 
5204C 
5205C 
5205C1 
5206C 
5206C1 
5207C 
5207C1 
5208C 
mm 
ln. 
10 
.3937 
12 
.4724 
s .5906 
17 
.6693 
20 
.7874 
25 
.9843 
25 
.9843 
30 
1.1811 
30 
1.1811 
35 
1.3780 
35 
1.3780 
40 
1.5748 
Width 
14.29 
15.88 
15.88 
17.47 
20.64 
20.64 
22.23 
23.81 
26.99 
26.99 
30.16 
30.16 
.5625 
.6250 
.6250 
.6876 
.8125 
.8125 
.8750 
.9375 
1.0625 
1.0625 
1.1875 
1.1875 
967 
1 260 
1 530 
1 980 
2 700 
3 150 
3 150 
4 590 
4 590 
6180 
6 180 
7 640 
Single and 
double sealed 
grease 
16 000 
IS 000 
12 000 
10 000 
9 000 
8000 
8 000 
7 000 
6 000 
s 600 
Fillet radiusl) 
Basic radial load rating 
mm 
30 
32 
35 
40 
47 
52 
52 
62 
62 
72 
72 
80 
ln. 
1.1811 
1.2598 
1.3780 
1.5748 
1.8504 
2.0472 
2.0472 
2.4409 
2.4409 
2.8346 
2.8346 
3.1496 
mm 
.64 
.64 
.64 
.64 
1.00 
1.00 
1.00 
1.00 
1.00 
1.00 
1.00 
1.00 
ln. 
.025 
.025 
.025 
.025 
.040 
.040 
.040 
.040 
.040 
.040 
.040 
.040 
Dynamic 
7 610 
10 400 
11 400 
14 300 
19 000 
20 800 
20 800 
28 600 
28 600 
37 700 
37 700 
44 900 
1710 
2340 
2560 
3210 
4270 
4680 
4680 
6430 
6430 
8480 
8480 
10100 
Static 
4 300 
s 600 
6 800 
8800 
12 
14 000 
14 000 
20 400 
20 400 
27 soo 
27 soo 
34 000 
Grease 
16 000 
IS 000 
12 
10 
8000 
8000 
7 000 
s 600 
Oil 
22 000 
20 000 
17 000 
IS 000 
13 000 
11000 
11 000 
9 soo 
9 soo 
8000 
8 000 
7 soo 

Per SKF Bearing literature:

Bearing 5208C 80mm OD

Dynamic Rating: 11,100 lbs

Static Rating: 7640 lbs

Assume no thrust load.

Equivalent radial load= P= 1314.75 lbs (from above)

C = Dynamic load rating = 11,100 lbs

L10 life = (C/P)^3 = (11,100 / 1314.75)^3 = 601 million revs

L10 life is 90% reliability of a single bearing life under defined loading.

Bearing dia" 80mm => 9.9" circumference

Rail circumference: 2\*262\*PI=1,646.19"

Bearing rev/dome rev = 1646/9.9= 166.2626 brg rev/dome rev

601E6/166 = 3.6205E6 ≈ **3.6 million dome revs for L10 bearing life**

*Assuming 20 year life on bearings, this give ~500 dome revs/day.*

Machine generated alternative text:
_TüRN 

From drawing: 102160

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**Dome operating parameter practical limitations:**

All the Palomar domes, and especially the P60 & P48 domes, exhibit unique behaviors as a function of environmental conditions and actual construction tolerances which show themselves as increased driving torque, intermittent interference between moving and fixed parts, excessive noise especially at lower operating temperatures, and excessive wear of highly stressed components. (i.e. bearings, wheels, rails, over-travel restraints)

There are lateral and radial forces generated due to thermal variations in dome structure from differential expansion of moving steel structure as compared to fixed structure anchors to concrete. This can be caused by ambient temperature extremes, or differential heating of the dome by the sun. Experience shows that these variations cause signification changes in the dimensional interface between moving and fixed parts, which can cause wheel to rail misalignment.

Excess and varying lateral loads can also be caused by wind induced loads. These variable loads can induce skidding and "creep" forces in the wheel to rail contact. In addition to environmentally induced creep, the construction tolerance of wheel to rail misalignment can cause significant lateral forces. The subject of skidding and creep is analyzed for various cam follower bearing designs and has been given specific attention in the design of the TMT dome bogie design (see attached "TMT Enclosure - Azimuth Bogies PDR Report" ). This analysis was also used in defining the dome bogie system design for the CCAT telescope enclosure.

 

The lateral (creep) forces that arise come from having the wheels not perfectly aligned with the direction of travel. Figure 6 of the attached reference shows the "normalized creep forces" which are the lateral forces normalized to the sliding forces (i.e. 1.0 = pure sliding). You can see at 0.1 degrees misalignment (about 1.7mm per 1000mm) the lateral force is about 50% of the static sliding force.

The design of the P60 and P48 from the rail upwards are identical, but the construction methods and tolerances held are not. We have seen periodic failure and excessive wear of components of each of the systems, which theoretically should see very little load under the operating conditions, and should have a much longer operating life. Most of the failures appear to be the result of high lateral forces. It is presumed that these high lateral forces are a result of the environmental and construction induces misalignments between the bogie wheels and rail described above. Any assessment of the long term durability of the specific dome bogie system must consider these real world conditions when evaluating changes to the system's duty cycle or operating parameters, such as acceleration and maximum velocity, cycles per/year, and resulting time before failure of system components.

Given the operational experience with the P60 and P48 dome systems under previous increases in duty cycle, the result of operating under further increases in operating parameters will likely result in an accelerated failure rate of highly stressed components, and therefore lead to higher maintenance burden, increased operating costs and downtime.