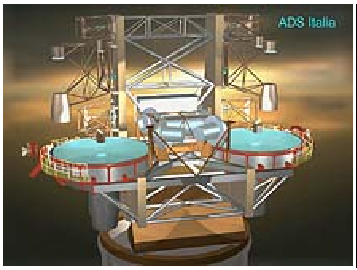

LBT PROJECT

2 X 8,4m OPTICAL TELESCOPE

Instrument Rotator and Cable Chain

Cable Chain Torque Estimate

	Signature	Date
Prepared	Robert Meeks	11-Mar-07
Reviewed		
Approved		

1. Revision History

Issue	Date	Changes	Responsible
a	11-Mar-07	First Draft	Robert Meeks

2. Table Of Contents

3. About this document

3.1. Purpose

The purpose of this document is to define the cables and hoses carried by each rotator cable chain and to estimate the torque required to turn the cable chain..

3.2. Reference Documents

[RD 1]	670s012a	Instrument Rotator and Cable Chain Mechanical Design Calculations
[RD 2]	External	Test Report on cable stiffness measurements (included in Appendix

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4. Torque Estimating Methodology

The torque required to operate a filled cable chain can be estimated by considering three sources: the frictional torque from the bearing, the work required to bend the contents of the chain, and the work required to lift the contents against gravity. The first two of these sources always act while the final force depends on the orientation of the cable chain with respect to gravity.

The maximum frictional torque of each bearing was estimated in RD 2 by scaling the specified maximum torque of the Bent Gregorian Rotator Bearing by the square of the pitch diameter of the bearing. This essentially assumes that most of the frictional torque is produced by the sliding friction of the seal and the preload force within the bearings. The cable chain bearings have the same type of seals as the instrument rotator bearings but they are believed to be assembled without preload. This would make the frictional torque lower. The actual measured frictional torque in the Bent Gregorian bearing is about an order of magnitude lower than the specified value as well. These factors combine to make the torque estimated following this procedure very conservative.

The work required to lift the cables against gravity is found from a straightforward calculation of their weight per meter and an assumed unsupported length of 3.5 meters based on the diameter of the inner tray. The weight per meter for the cables was estimated from catalog data. This is also considered conservative.

The bending torque was found by assigning a measured value to each large cable and a small value to each small cable. The large values were obtained from a measurement made by the Lucifer team in Germany. The report of that measurement is included in an Appendix to this document.

These three primitive torques were then summed to arrive at the total toque required to turn a cable chain.

5. Bent Gregorian Cable Chain

5.1. Cable and Hose List

The list of cables populating the Bent Gregorian Cable Chain is shown in the table below along with additional data used for calculating the torque:

Qty	**Desc.**	**Type**	**Dia (m)**	**Area (m^2)**	**Wt (kg/m)**	**Len. (m)**	**Hanging Mass (kg)**	**Bend Force (N)**	**Total Bend Force (N)**
10	Signal		6	28.3	0.1	3.5	3.5	0	0
2	Air	Poly line	6	28.3	0.1	3.5	0.7	1	2
2	Power	12 mm	12	113.1	1	3.5	7	20	40
4	Coolant	SS braid	20	314.2	2	3.5	28	20	80
2	Helium	VJ line	28	615.8	4	3.5	28	20	40
Total							**67.2**		**162**

5.2. Torque Estimate

These forces operate on an approximately 1.5 meter moment arm.

The total torque from all sources is:

Cable weight	989 Nm
Bending	243 Nm
Friction [RD2]	550 Nm

The total required torque is: 1782 Nm

6. Direct Gregorian Cable Chain

6.1. Cable and Hose List

The Direct Gregorian Rotator Cable Chain carries a similar set of cables:

Qty	Desc.	Type	Dia (m)	Area (m^2)	Wt (kg/m)	Len. (m)	Hanging Mass (kg)	Bend Force (N)	Total Bend Force (N)
10	Signal		6	28.3	0.1	3.5	3.5	0	0
2	Air	Poly line	6	28.3	0.1	3.5	0.7	1	2
2	Power	12 mm	12	113.1	1	3.5	7	20	40
4	Coolant	SS braid	20	314.2	2	3.5	28	20	80
Total							**39.2**		**122**

6.2. Torque Estimate

These forces operate on an approximately 1.5 meter moment arm.

The total torque from all sources is:

Cable weight	577 Nm
Bending	183 Nm
Friction [RD2]	1928 Nm

The total required torque is: 2688 Nm

Appendix

Test Report
Torque measurements on the He-flexlines for the LUCIFER closed cycle cooler

Werner Laun, MPIA Heidelberg, 21 Nov 2006

Test intention

LUCIFER will rotate around the central axis of the mounting flange. Therefore all cables and also the He-flexlines for the two cold heads have to go through a cable rotator. The flexlines are not very flexible and therefore we expect some additional torque to rotate them. The four lines (two supply and two return) will be mounted in a cable chain and bend for 180° with a radius of about 250 mm. We here did some simple measurements to have an approximate value of the expected torque.

Test set up

One identical flexline to the LUCIFER flexlines was used for the measurement. They were pressurized to 16 bars with Helium. One side was fixed on a piece of aluminum and screwed to the table. The other side was mounted on an easy linear stage which carried also a piece of aluminum. When the linear stage is moved the bending in the line is also moving. The side on the linear stage was pulled with a spring scale to measure the force needed to move the linear stage.

Figure 1: Test set up, right side fixed, left side on linear stage

Figure 2: left side moved for about 500 mm

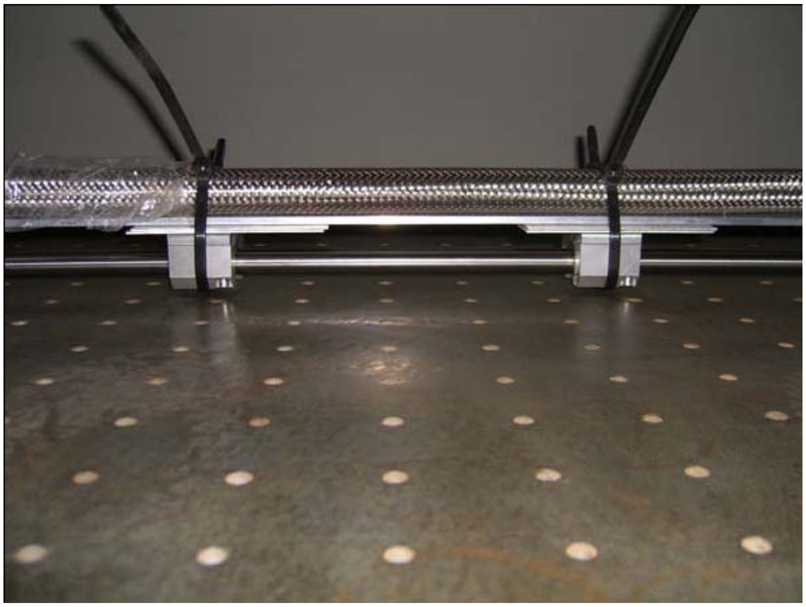

Figure 3: linear stage with fixed flexline

Test results

The distance between the right an the left side was changed from 385 to 485 and 585. This is the distance of the symmetry line. The line it selves is 28 mm in diameter. So the outside distance is about 413, 513 and 613 mm. The travel on the linear stage was limited to about 500 mm. We tried to move slowly and constantly.

Distance / mm	Force / N
385	18 - 22
485	16 - 18
585	12 - 13

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