TRIP REPORT – MAUNA KEA 31-MAY THRU 7-JUNE 2012
ELEVATION BEARING CHANGE

Trip Summary

A team from the VLA went to the Mauna Kea VLBA site to perform the replacement of the synchro side elevation bearing. The bearing had been producing metal particles in the grease for some time (refer to reports submitted by Tony Sylvester, MK Site Tech for details), so it was determined inspection and replacement were necessary.

The replacement took place between 31-May and 7-June 2012. The VLA staff participating in the trip were:

Ramon Gutierrez
Martin Lopez
John Wall
Adrian Zamora
Tommy Montoya
Ken Lakies
Matt Evatt

This group arrived about 5 days earlier than the rest of the Tiger Team who were installing a new C-Band receiver and running of new fiber optic cable from the station building to the telescope.

Trip Details

Wednesday 30-May 2012

Travel day from ABQ to Kona, HI.

Thursday 31-May 2012

Traveled from Kona to the MK VLBA site Thursday morning to unload the container and prepare for the job. I called the crane vendor (Arborist Services) to verify that the crane would be arriving the next morning as agreed. Unfortunately, there was some miscommunication between the contractor and the purchasing department concerning an additional charge required to list our employees on the vendor's certificate of insurance, so the crane was not scheduled to be at the site as agreed. Purchasing worked with the vendor to solve this problem, and Tony Sylvester, one of the MK Site Techs, arranged the required agricultural inspection of the crane for the next morning at very short notice. By the end of the day, the crane was again expected to arrive in the morning.

Friday 1-June 2012

The crane did arrive at the agreed time Friday morning. Some members of the team worked on drilling the holes in the pillow block platform for the jacking beam while the rest of us determined how to deal with the HVAC equipment that was mounted on the synchro side that had to be removed in order to get the pillow block down. We ended up calling a local HVAC contractor to come to the site the following morning to vacuum the refrigerant out of the system.

Saturday 2-June 2012

The HVAC contractor arrived at the agreed time of 8:00 AM this morning and safely emptied the system of refrigerant. By the time we left, we had accomplished the following tasks:

- Completed drilling all holes in the synchro side PB platform (including tapping one hole) for the jacking beam. Note that in one hole, a bit broke off and we elected not to spend time removing it because the hole was located where it wouldn't have been subjected to a tensile load.
- Removed the HVAC enclosure that was mounted on the hand rail. Some of the connections on the bottom of this enclosure were not compression fittings, so Tommy unsoldered them.
- The HVAC flex hoses that penetrated the wall into the vertex room were disconnected at their lower ends.
- We attempted to disconnect the compression fittings on the upper ends of these hoses inside penetrations, but we found that the fittings would not fit through the holes. Instead, Tommy unsoldered these connections.
- The support structure holding the HVAC hoses was cut off and removed along with the hoses. This was required because the support structure was positioned directly above the lug on the PB from which we had to pick it up. All welds holding the pillow block in place on the platform were cut using a cutting wheel on a grinder, except for one that was behind a handrail. That final weld had to be torch cut.

Notes on Wind Speed

The wind speed during the morning on Saturday indicated peak gusts of up to 38 mph. The crane operator told us that the maximum allowable wind speed for using the crane was 30 mph. However, that figure applies at sea level where the density of air is about 40% greater than at our elevation. The wind force on an object is related to the sectional area presented to the wind, the wind velocity, and the air density. I calculated that 30 mph wind at sea

level would exert about the same force as 37 mph wind at our altitude. I felt this was a safe condition in which to continue using the manlift.

Sunday 3-June 2012

Today was a critical day. We were able to complete all the remaining preparatory work; we worked about 16 hours to do this.

Before lunch time today we were able to:

- Install the two round structural supports
- Measure, cut, and install the square structural support
- Lift and bolt down the jacking beam.
- Remove all of the pillow block bolts. None of the PB bolts were too tight to remove with the large electric impact driver.

Notes about removing insulation

In order to make up for lost time, Tommy and Adrian came up with the idea of cutting out a small section of insulation from the location where the structural support lugs were to we welded on, then reinstalling that section after the lug was installed. See the figure below for details. This idea saved at least one full day at the end of the job by eliminating the need to reinstall large pieces of insulation. It should be noted that the patch job in these locations looks very uniform and professional.

After lunch we were able to:

- Place the jacks and to lift the telescope up.

  Note that we had trouble lifting the pillow block up from the platform. It initially appeared that a corner was still welded down, but we determined that wasn't the case. Instead, when we did finally lift the PB up, it moved about ¾" forward (not outboard, but forward). This indicated that the PB had simply been hanging on one of the PB locating blocks welded to the platform.

  The source of this ¾" movement is not clear. It is possible that the pillow block simply rotated on the axle, but because it was difficult to move back into place this seems unlikely.

  At this time Ken observed that the bull gear moved about 3/8" toward the synchro side of the telescope. When we sat the telescope back down, it moved back about .275" for a net motion of .100" toward the synchro. This must be related to the ¾" of forward motion we observed the pillow block to undergo once it was suspended by the axle and free to move.

  Lifting the pillow block clear of the supporting platform required about 5900 psi. In Fort Davis on the encoder side it required 6200 psi.

- Set up and remove the taper coupling from the axle.

  Note that the taper coupling was already loose; no pressure was required to move it. We did not expect this; later, after determining that the inner race of the bearing was broken, it made sense that the taper coupling was loose.

Some observations of the grease after the cover plates were removed from the bearing: Although heavy flushing with grease had slowed down the amount of new metal pieces seen coming out of the bearing, when the cover plates were removed from the bearing and the grease was examined, we found metal flakes in the grease like glitter (see the following figures). Heavy greasing probably cleaned out a small path in the bearing between the grease fitting and the particular place where grease usually came out, but the metal was still there in all other areas.

Monday 4-June 2012

Today our goal was to remove the pillow block and to replace the bearing, but due to high sustained and peak winds we were not able to lift the dish.

Tuesday 5-June 2012

Today we removed the pillow block and took it down to the ground, replaced the bearing, and reinstalled the pillow block back in place on the telescope.

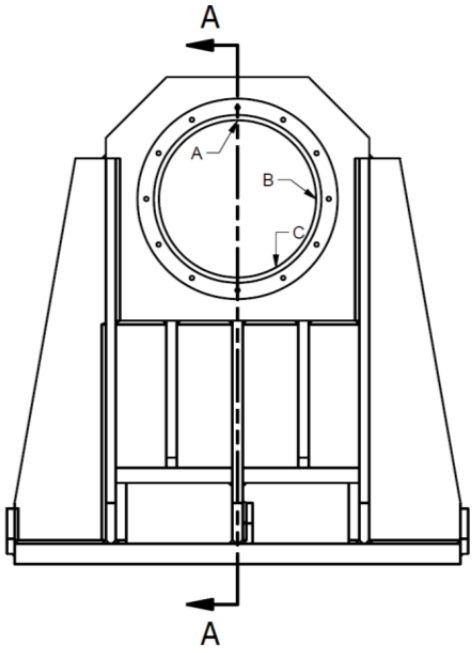
The existing bearing was a Rollway 23056MBKW33C3. The old bearing slid out easily, and the new bearing slid in easily with no press force required.

Bearing Failure Mode

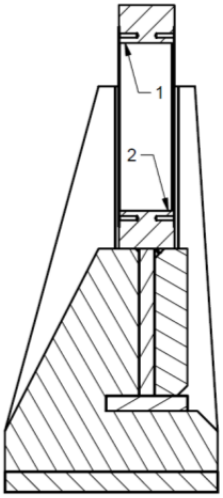
The bearing will be inspected thoroughly when it arrives back at the VLA, but one failure mode was obvious; the inner race was cracked entirely through as shown in the following pictures:

Measurement of Pillow Block ID

The nominal ID of the PB bore from the VLBA drawings is 16.5354 +.002/-.000 inches. The PB ID measurements are shown in the following figure and table:



VIEW FROM OUTBOARD



SECTION A-A

Location	Measurement
A1	16.5315
A2	16.5305
B1	16.5395
B2	16.5389
C2	16.5332

Allowable ID Range: 16.5354 – 16.5374 (= .002)

Measured ID Average: 16.5347 –> .0007 undersized

Measured ID Range: .009 –> Exceeds allowable tolerance range of .002 by .007 inches

Measurement of Reduction in Roller Bearing Clearance

After the bearing was inserted and the PB lifted back up to the platform and hung off the bearing, the roller bearing clearance was checked to find the initial clearance so we could determine when we had reached the required .006 inches of reduction in clearance by tightening the taper coupling.

Because there was no tolerance range stated in the procedure, Ramon and I looked up the range of RIC in the manufacturer's literature, and it is .0045 to .007. I put this range in the procedure.

The initial clearance was .013; we achieved a reduction in clearance of .0055 inches.

After the reduction in clearance was achieved, we set the dish back down on the pillow block platform, put in three pillow block bolts and left the site for the evening.

Wednesday 6-June 2012

Depth of Bearing in Pillow Block

I had measured the depth of the bearing in the pillow block after the pillow block was removed and set on the ground of about .678 from the machined face of the PB to the edge of the outer race. However, I later realized that this measurement didn't mean anything as the bearing had probably slid in the bore between the time we removed the coupling and set the PB on the ground. This measurement was supposed to ensure we put the bearing back on the axle at the appropriate axial location, but this is the wrong measurement to use for that purpose. Instead, the distance from the end of the axle to the outer race of the bearing should be noted, and the distance from the end of the axle to the PB should also be noted. The bearing location became a problem for us as after we installed the PB in its original location, the bearing ended up being flush against the inboard lip on the PB. Because this was the floating side, the bearing should have ended up with clearance on both sides so it could move either in or out as required.

After installing a dial indicator to measure axial movement of the bearing relative to the pillow block and a dial indicator to measure axial movement of the bearing relative to the axel, we rotated the elevation axis. We found no motion between the bearing and the axle, indicating that the taper coupling was holding, and we found very little motion between the bearing and the pillow block (a few thousandths and only at certain points in the rotation). The motion, or lack of motion, we found indicated that the bearing was most likely stretching the dish section of the telescope, which meant there was an axial load being applied to the bearings. I felt this was not acceptable, so I decided that we needed to move the bearing in the outboard direction relative to the pillow block. We spent the entire day doing this.

Moving Bearing Outboard

Because lifting the pillow block up completely was made complicated by the fact that it wanted to move about ¾" forward when free, we decided to leave the PB bolts attached and to jack up the dish, measuring the bearing clearance on the top and bottom of the bearing to determine when the bearing was no longer supporting any vertical load.

Note that we first tried loosening the taper coupling then rotating the elevation axis in the hope that the bearing would move out on its own; however it did not, so we performed the procedure I am describing.

After determining the bearing was not loaded vertically, we attempted to pry the bearing out from the inboard side. We could not move it as there was no good location to place pry bars in this area. So we decided to use the inboard bearing cover as a press. We first had to find some spacers to place between the cover and the bearing; we used some ¾" nuts with welding rods stuck to them as handles. The nuts were placed under cover bolts, and then those bolts were tightened. Eventually, we got the bearing to move outboard about ¼", which was enough to ensure both that it had sufficient range of axial motion, and that the bearing grease channel on the outer race was aligned with the grease fitting on the outside of the pillow block.

The next challenge was to re-tighten the taper coupling.

Re-Tightening Taper Coupling

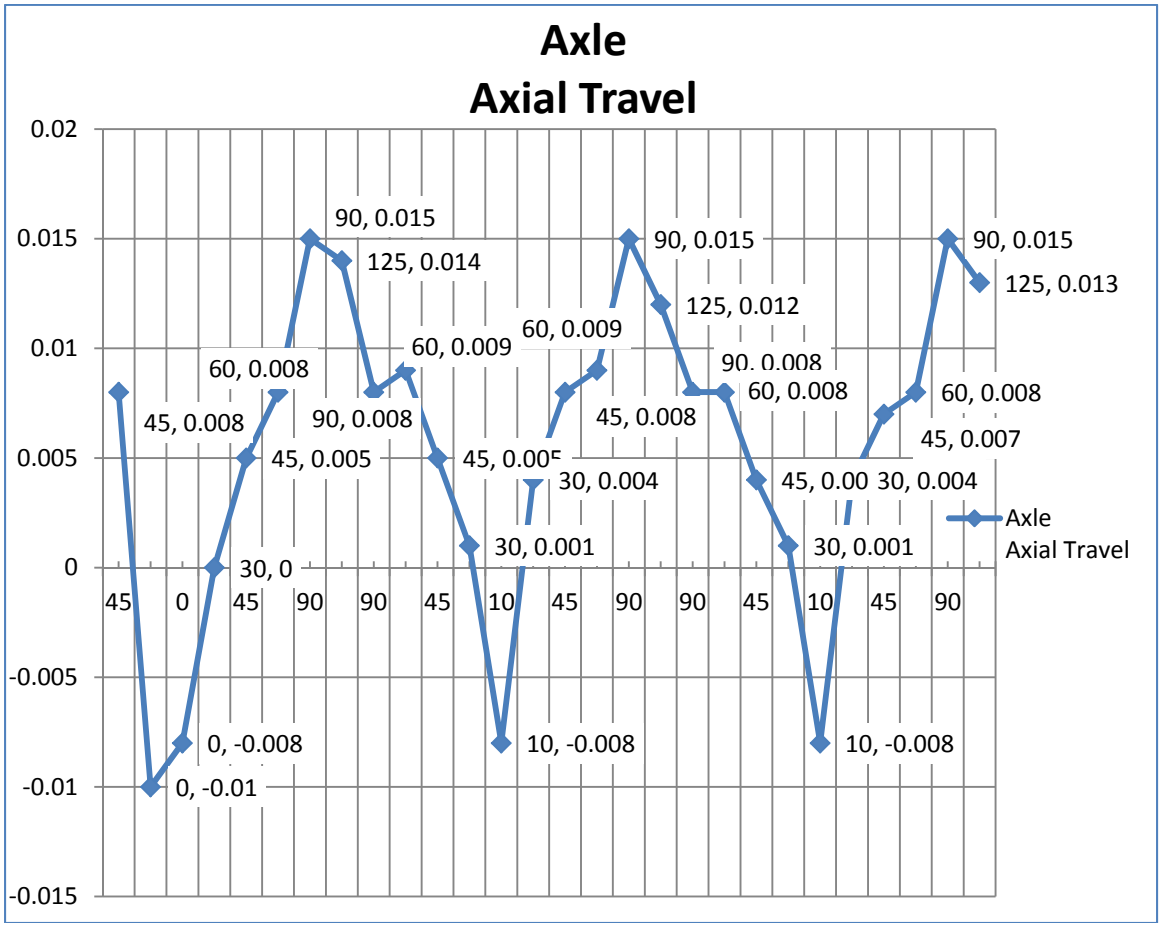
Re-tightening the taper coupling with the pillow block bolted down was a difficult process even though we had the weight of the dish supported by jacks and not by the bearing. One contributing factor to the difficulty of this operation was that because of the fore-aft movement of the pillow block noted above, placing it back in its original location caused it to be loaded in the fore-aft direction. This, in turn, meant the bearing was not free as it was being subjected to a side load even though the vertical load was close to zero. The other contributing factor to the level of difficulty was that the hydraulic taper coupling installation nut would not fit the threads on the taper coupling. This problem has presented itself before; I believe that in Fort Davis in 2011 we used the old taper coupling because it fit where as the new taper coupling didn't fit the hydraulic nut. However, we tested the hydraulic nut on the taper coupling threads while still at the VLA, and although it was a tight fit, we were able to screw the nut on. The taper coupling is split, though, and apparently when installed on the axle, it opens up a little. This kept the hydraulic nut from fitting in the field. I will have the machine shop open the threads on the nut to ensure it fits in the future.

Note that the hydraulic nut fits some taper sleeves but not others. I believe this is due to differences in different manufactures' threads.

Finally we were able to get the bearing taper coupling reinstalled with about .005" RIC.

Thursday 7-June 2012

This morning we ran the elevation axis while watching a dial indicator that was configured to read axial motion between the pillow block and the axle. The following graph shows the results. Note that the axle is running smoothly with no sounds evident



The graph shows that there is a maximum of .007" of hysteresis occurring at 90 degrees, but that the repeatability when moving the axis in the same direction seems to be better with a maximum difference of about .004" at 30 degrees travelling up.

Friday 8-June 2012 – Saturday 9-June 2012

Travel days for John Wall, Adrian Zamora, and Matt Evatt from Kona, HI to ABQ.