Celestron CGE Mount PEC Improvement

By Mike Dodd, May 26, 2006

Introduction

The Celestron CGE is an excellent mid-range telescope mount. It is solidly-built, has a payload capacity of 65 pounds, and uses a high-grade worm and worm gear, along with Pittman servo motors.

In the past two years, Celestron has made major improvements to the firmware in the motor-controller and hand control. It is now possible to achieve a quick polar alignment that yields excellent pointing accuracy. Furthermore, Celestron's NexRemote software, which emulates the hand control, allows all operations to be performed from a personal computer connected to the CGE.

Periodic error

Even though the CGE's RA worm is supposed to be very good, it typically exhibits 25 to 35 arc seconds of periodic error (PE) peak-to-valley. PE can be reduced by using the CGE's built-in periodic error correction (PEC) feature, which issues motor speed corrections as the mount tracks across the sky. Celestron's free PECTool software can average several PEC training runs and upload the result to the CGE for a smoother correction curve.

However, some CGE imagers are frustrated that even with PECTool, PE isn't corrected as well as it should be. There seems to be a lot of "noise" still present. What's going on? Why isn't this "noise" reduced as well as the main 480-second worm periodic error?

It's the reduction gears

This "noise" comes from the Pittman motor reduction gearbox. Since the gears here are rotating at different speed ratios than the worm, PEC cannot eliminate them. Furthermore, most of the noise comes from the two gears closest to the output shaft, and these gears are made of sintered metal. Sintering compresses metal grains under high temperature and pressure to form a solid; viewed under a microscope, it's easy to see the voids between the grains – in other words, the gears have a rough surface, which increases friction between them. This is the source of the "noise" on the PE curve.

It turns out Pittman offers these motors with three types of reduction gears: Sintered, cut-steel, and wide-face cut-steel. Unfortunately, Pittman won't sell us a CGE motor with cut-steel gears, because that part number is proprietary to Celestron. However, they *will* sell a stock motor from the same line having the same 60.5:1 gearbox and wide-face cut-steel gears.

Here is a quotation from an email I received from Pittman, describing the motor, the part number, and the price.

...we do have a motor in our stock program that may work The part number I am looking at is ***GM8724S020-R1****. ([...] go to <u><http://pennmotion.com></u>, click on Motion Express, click on GM8000, click on this part number. This will show data sheets and a drawing). This motor is 24 volts but is rated at 12 volts, has 60.5:1 gear ratio, wide face gears and ball bearings in both the motor and the gearbox. The only thing that might be a problem is that this motor has terminals instead of leadwires. The pricing is as follows:*

Pittman P/N: GM8724S020-R1   1 piece $114.14 each

We currently have this motor in stock. Payment terms would be COD or credit card (Visa or MasterCard). Shipping terms are FOB - Harleysville, PA.

I obtained one of these motors, and substituted the wide-face cut-steel gears in my CGE's original RA motor. They drop right in. In reality, only the two final gears are cut-steel; the other two appear to be sintered metal, but I replaced them all.

My tests show that the cut-steel gears *significantly* reduce the asynchronous noise on the PE curve. With the main PE term virtually eliminated by PECTool averaging several training runs, all other frequencies are below 1.5 arc seconds, and most are lower than that. Another person who also replaced his gears got similar results, although not quite as good (I have a CGE-9.25 and he has a CGE-14, so maybe that was a factor).

So there you have one option that seems to reduce the gear noise. $114 is a lot to pay for a few gears, but they definitely made a difference on my CGE.

(Note that the motor itself won't work in the CGE because it's for a different voltage rating and doesn't have the shaft encoder. But you can probably sell it on eBay with the sintered gears and recoup some of your investment.)

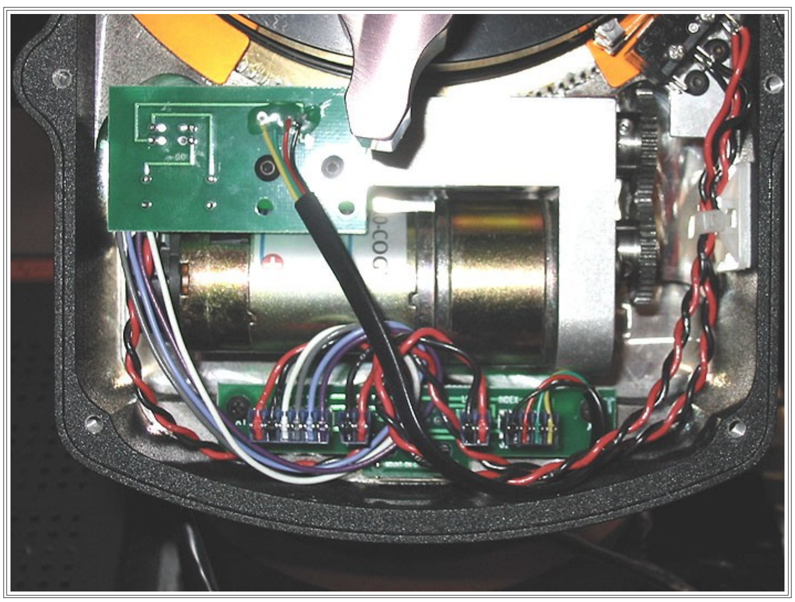
CAVEAT: I have performed no testing on these gears other than to use them in my CGE for about a year. Pittman indicates they are interchangeable, and my experience seems to verify this. But I have no idea if Celestron' proprietary part number changed any gearbox dimensions or gear specifications. Just so you know.

In the following sections, I show how to remove the RA drive, open the Pittman motor, replace the gears, and put everything back together.

A word of caution: You should attempt this work only if you are comfortable working with tools and small parts. Also, the instructions do not include each and every step, so you should be able to figure out the details yourself. Needless to say, this work probably voids the Celestron warranty, so consider that as well.

Removing the RA drive

The first step is to remove the motor and worm assembly from the RA drive. Here is a picture of the RA drive internals.

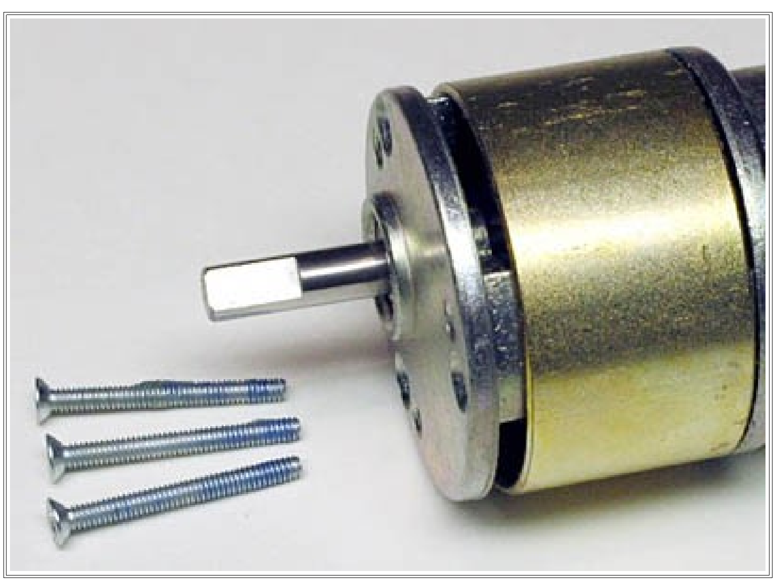


- Loosen the RA clutches and carefully move the telescope to a resting position, probably against one of the limit stops. Remove the four screws holding the RA drive cover, and remove the cover.
- Remove the small circuit board that contains the RA index sensor (green rectangle in upper-left area of the photo), and set it aside.
- Note the location and orientation of the motor power and encoder connectors (*take a photo!)* and unplug them. In the picture above, these wires are on the left end of the connector strip. The motor wires are red and black, and the encoder wires are white, gray, blue, and violet.
- Using an 11mm wrench, remove the two bolts holding the drive assembly in the housing. The bolts are located on the bottom of the housing.
- Remove the drive assembly and identify the two sets of plastic shims on the side where the worm is visible. Remove these shims (grease holds them on) and set them aside.
- Take the drive assembly to a clean, well-lighted workbench for the rest of the work.

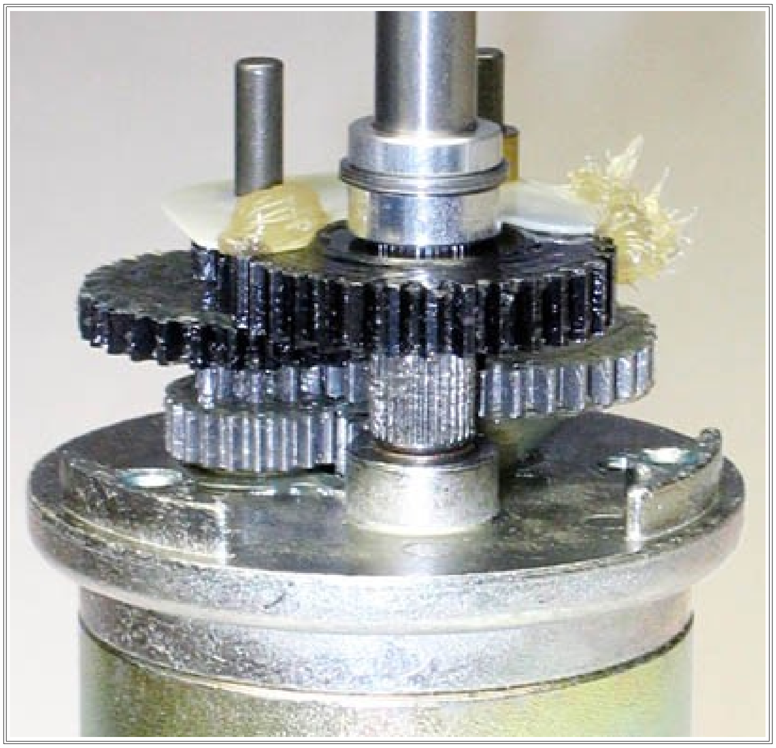
Removing and opening the motor

- Use a hex wrench to loosen the two set screws holding the spur gear to the motor shaft, and remove the gear.
- It's not necessary to remove the spur gear from the worm shaft.

- Please refer to the photo below. Remove the three Phillips screws that hold the motor to the bracket, and remove the motor.
- Remove the three flat-head Phillips screws holding the cover on the gearbox. These might be hard to turn due to thread-locking compound.
- Slide the gearbox cover off the motor shaft. Press your thumb on the end of the output shaft to hold it in place, and work the cover up. If the cover binds on the shaft as it slides off, it's probably catching on a burr left by the set screw; gently use a fine file to smooth any burr until the cover will slide easily.
- *Look carefully for washers and spacers on the output shaft, or stuck to the inside of the gearbox cover. Note the "stack" of hardware on the shaft, and be sure it is reassembled the same way.*
- Remove the cylindrical gearbox shell.



Unbutton the gearbox on the new Pittman motor in the same way. This photo of the new motor shows the gearbox with the sleeve removed. Notice the two dark-colored cut-steel gears on top of the stack. Also notice how much taller the top gear is than the gears below it; this is the “wide-face” gear.



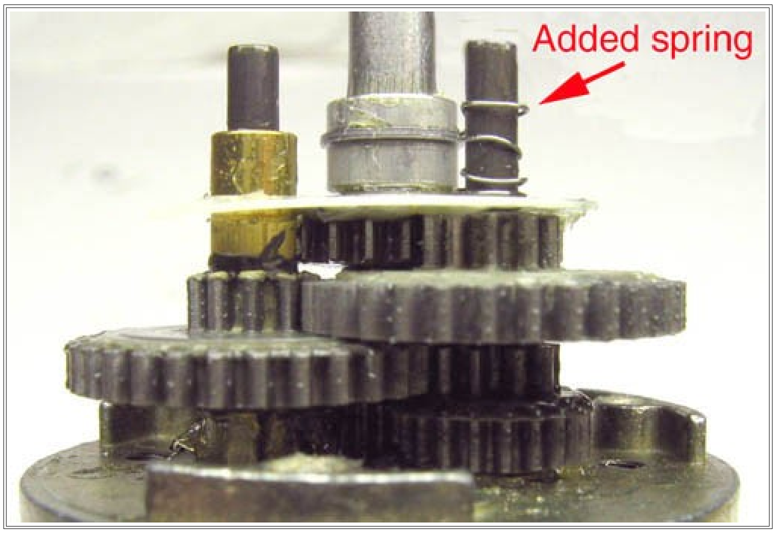
There's lots of grease, and you might want to scrape off as much as possible and save it for later. Remove the flat white plastic piece by sliding it up the two shafts. The brass sleeve will slide easily, but the other hole will probably be tight; slip a screwdriver under it and work it up.

A note about the white plastic piece

Apparently the purpose of the plastic piece is to hold the top gear in place, although the spacers on the main shaft ought to do the job once the the gearbox cover is installed. Nevertheless, the plastic piece presses hard against the top gear in such a way that the gear teeth rub against it. Here is a photo of the underside of the plastic piece I found when I first disassembled the RA motor in my CGE

The broad worn area near the brass sleeve is the result of the top gear teeth rubbing against the plastic. Part of the problem was that the sintered metal teeth had “flash” (feathers of metal) on their edges, but the problem was compounded by how tightly the plate pressed against the top gear.

To reduce this pressure (and wear), I enlarged the right-hand hold with a small round file, so the plastic piece would slide easily on its shaft. To provide some pressure, I added a small coil spring between the plastic and the gearbox end cover, as shown here.



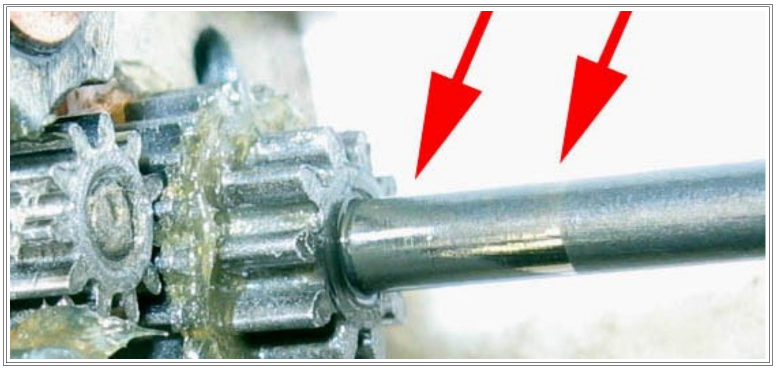
Swapping the gears

Here is a picture of the new Pittman motor with the plastic piece removed and all four gears visible (there is one more gear on the motor shaft beneath this stack).

Remove all four gears from the original motor, then replace them with the corresponding gears from the new motor. Be sure to apply a thin coat of grease to each shaft before sliding the gear onto it, and a heavier coat to the gear teeth. Install the original sintered-metal gears in the new motor (you might want to list this motor for sale on eBay, since it's perfectly good for applications that aren't as critical as a telescope drive).

A note about shaft wear

You might see some uneven wear patterns on the shafts after you remove the gears. Here is a photo of what my RA drive motor looks like.



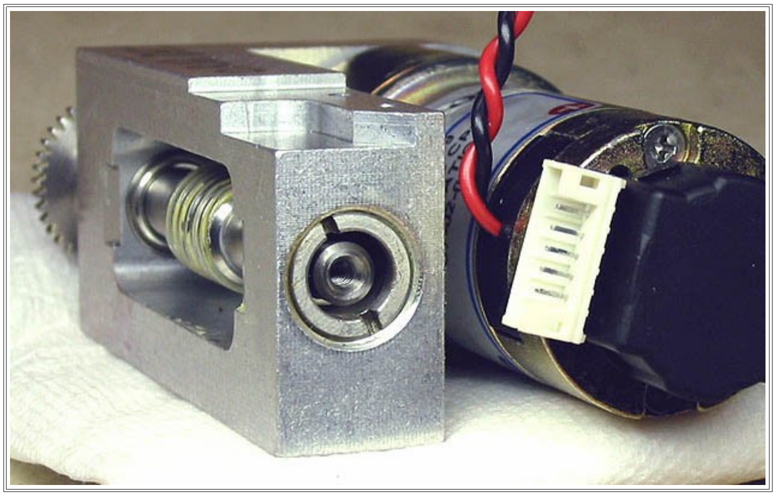
This indicates the gears are wobbling on the shaft, and this probably contributes to the noise on the PE curve. Alas, I don't know how to fix this, short of replacing the shafts with larger ones made of hardened steel, and drilling-out the gear holes. I haven't attempted this.

Reassembling the motor

- After installing the gears, add the spacers and washers on the main shaft.
- Install the white plastic piece that presses on the top gear.
- Replace the cylindrical gearbox shell.
- Slide the gearbox cover onto the motor shaft, and align it so it fits onto the top of the gearbox shell..
- Secure the cover with the three flat-head Phillips screws.

Worm Thrust Bearing Adjustment

Before mounting the motor on the bracket, you might want to check the tightness of the worm bearing. I've heard several reports that this came from the factory adjusted very tightly. If when you turn the spur gear on the worm shaft, it feels “bumpy,” it's likely the bearings are too tight. This photo shows the bearing adjustment on the end of the worm shaft.

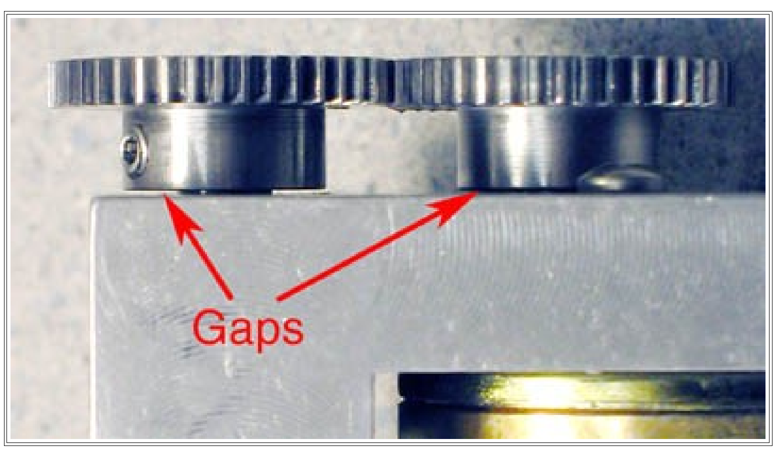


The adjuster is the large circular piece with the two slots. Use a *very* large flat-blade screwdriver that's wide enough to span both slots, but not large enough to scrape the threaded hole that the adjuster screws into. The adjuster is difficult to turn because a locking compound was applied when it was assembled. However, if you hold the bracket in a vise and twist counter-clockwise carefully, the adjuster will turn.

Turn it counter-clockwise slightly and check the feel of the worm shaft. Adjust until turning the shaft feels slightly “bumpy” but not silky-smooth. *Caution: If you adjust it too loose, the worm shaft will have lateral movement that will completely mess up the CGE's RA alignment, tracking, and autoguiding. It's better to be too tight than too loose.*

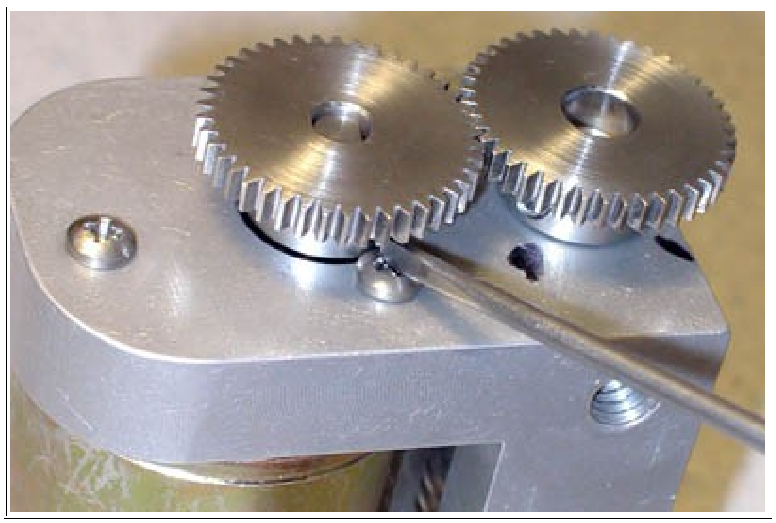
Final steps

- Attach the motor to the bracket using the three Phillips screws. Tighten the screws snugly, but do not completely tighten them yet.
- Install the spur gear onto the motor shaft. As shown in the photo below, be sure to leave gaps between the spur gears and the mounting bracket.



- Tighten the two set screws. *Important! Be <u>sure</u> one of the set screws bears directly against the flat area on the motor shaft. Rotate the gear back-and-forth as you tighten this screw to be sure it seats on the flat. If it's tightened off-center, it will loosen in operation and cause backlash in the gear train.* After the first set screw is tightened, tighten the second one.
- While tightening the Phillips screws, push the motor spur gear gently toward the worm spur gear. Remove as much play as possible, but don't make the mesh too tight. There should be a tiny amount of lash between the gears.
- With the gears properly meshed, tighten two of the Phillips screws. The third screw is impossible to reach

with the gear installed, but you can tighten it with the edge of a small screwdriver, as shown here (move the screwdriver laterally to turn the screw). Apply a thin coat of grease to the spur gear teeth.



- Replace the motor and worm assembly in the reverse order of the steps listed above under *Removing the RA drive.* Remember to put the plastic shims back on the face of the bracket. Make sure the worm is meshed correctly with the worm wheel, and apply slight pressure as you tighten the 11mm bolts.
- Once the bolts are tight, connect the motor power and shaft encoder cables.
- Loosen the RA clutch and power-up the CGE. Ignore the prompt to find the switch position and begin an alignment. Instead, use the left and right direction keys to slew the mount in RA. Listen carefully for binding as the worm wheel turns; if the motor slows dramatically, the worm mesh is too tight. Rotate the worm wheel about 30° in the opposite direction, then loosen the 11mm bolts, adjust the worm assembly again, and tighten the bolts. Test again, and repeat the process until the RA worm wheel rotates without serious binding (but expect a small amount, since many CGE worm wheels are not perfectly concentric).

So there you have it. Replacing the RA drive motor reduction gears eliminates a lot of noise on the periodic error curve, and makes it much easier to autoguide while imaging.