The R-390A Cosmos PTO repair and calibration

Tom Marcotte has posted some very informative and beneficial information on the R-390 list forum about the R-390A Cosmos PTO repair and alignment/calibration. They are so worth while that I have collected most of them here to make it easier for someone to find them. Thank you, Tom for taking the time to post them. Larry Haney, 12-8-2022.

Date: Mon, 13 Sep 1999 18:02:20 -0700 (PDT)
From: Tom Marcotte <courir26 'at' yahoo.com>
Subject: Re: [R-390] PTO query

The COSMOS does have an endpoint adjustment. It operates similar to the Collins et al endpoint adjust. When you look down at the front of the PTO, it will be the adjustment behind the cap screw on the right (almost behind the transformer). The linearity is the one on the left (actually there are 40+ screws for linearity under the cap). I wrote an article about this in Electric Radio. If you contact Barry Wiseman at er ‘at’ frontier.net, I'm sure he can get you a copy (he has copyright).

-----Larry Haney - No need for that, see end of this doc to see it.-----

I usually set up the PTO's with a little extra endpoint range as they "leak" range over time, just like a lawnmower that burns oil, you give it a bit of lagniappe. I give it one extra kc (1001 kcs in ten turns) and it burns off one kc in a year or so, and then it is right on without removal. This is a very predictable thing. It always drifts the same way.

Date: Tue, 19 Oct 1999 04:56:29 -0700 (PDT)
From: Tom Marcotte <courir26 'at' yahoo.com>
Subject: Re: [R-390] Cosmos PTO chicken or egg?

You did the right thing by setting the endpoint first. The rest of the PTO should be adjustable by the linearity screws, but 4 kcs is a bit of a stretch for a single point. If the main inductor is wound true, more or less, then the single point adjustments will serve to flatten out the corrector cam, but if the main coil is flawed, then the corrector cam will have a steep bow in it at that extreme point. This may cause a bit of drag in the PTO at that point. Don't sweat it and give it a try.

To answer your question, there will be little if any interaction between the endpoint and your erroneous mid-point, but you will have the opportunity to correct any last minute-minor endpoint error with the last linearity screw (keep it small though by doing your best endpoint adjustment first).

Date: Sun, 19 Mar 2000 08:46:44 -0800 (PST)
From: Tom Marcotte <courir26 'at' yahoo.com>
Subject: Re: [R-390] VRC runout and PTO alignment question

This is important to the performance of your rig. You should run the RF deck out to it's stop (either side is OK) and give the VRC (Veeder Root Counter) 35 kcs of overtravel (make sure your zero set gadget is about in the middle of its limited range). Then set the cams up at the prescribed frequency (7+000 or 7999 + 1 kcs I think the freq is). Then, set your PTO endpoints to 1000 kcs in ten turns. After all this is done, you can proceed with alignment. If you skip the above steps your alignment will be sub-optimal.

Date: Sun, 19 Mar 2000 18:40:08 -0800 (PST)
From: Tom Marcotte <courir26 'at' yahoo.com>
Subject: RE: [R-390] VRC runout and PTO alignment question

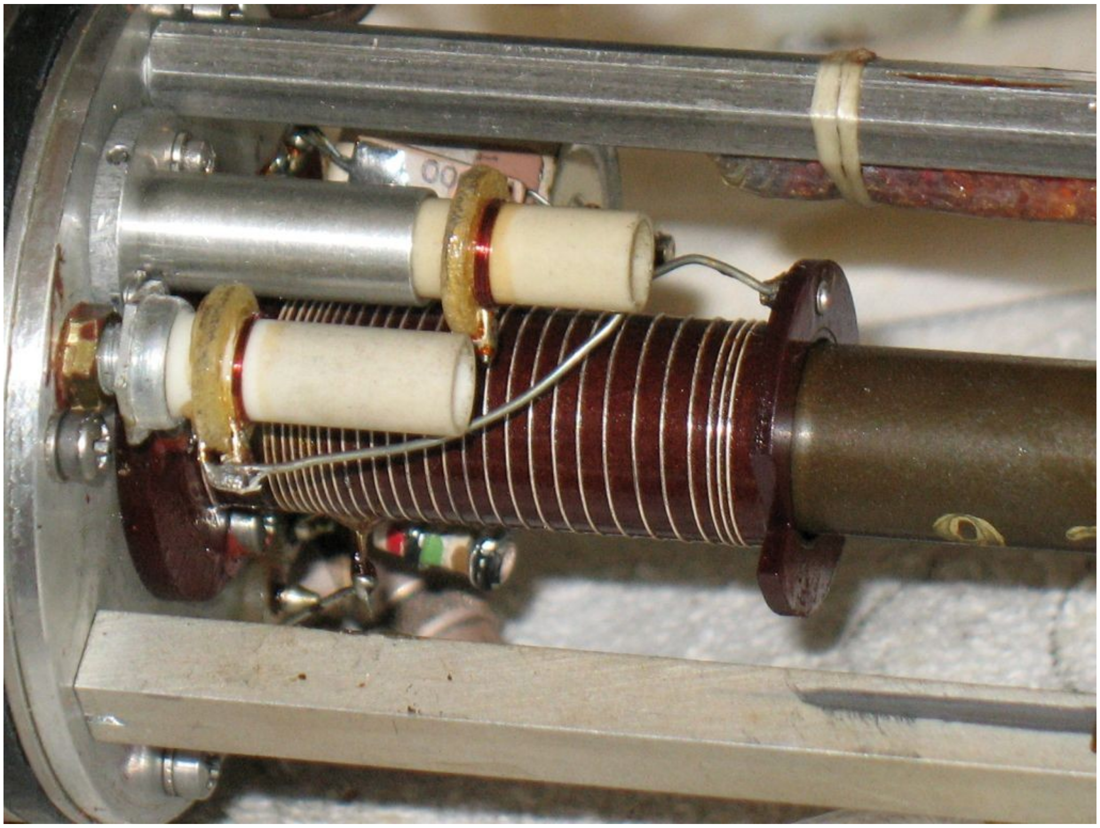
OK Dale, that is a fair question. Perhaps I was typing too fast. To set the overtravel, you should disconnect or remove the PTO, and then run the KC's knob over to its clockwise stops. Your counter should now read something on the order of the high side of the band that the RF deck is tuned to. With the knob at the stop, use your Bristo wrench to loosen the screw on the VRC (Veeder Root Counter) pinion gear, and make the counter read X+035. X is the band you are on. Example: If you are on the 7 Mcs band, make the counter read 7+035 (make sure your zero set adjustment is about at its center). Tighten the screw, and then never ever ever ever change this setting again. If you get confused setting the PTO up, adjust something else. Not this screw. See below. Then once this is set up, put the counter on 7+000 (i.e. 7 999 plus one more kcs) and set the cams up in line with their respective alignment marks for each of the six RF sections (see manual), and then never ever ever change these again. Adjust your PTO for 1000 kcs in ten turns (see the manual). When reinstalling the PTO, I find it safe to set the dial on 000, and then drop the PTO in place with about two turns from its own stop (or at 3455 kcs output if you have a counter or can listen to the PTO signal on another HF rig). Once the PTO is in, you can true it up with a local AM broadcast station.

Since the RF deck and counter are joined at the hip for life (see my orders above) the only adjustment you have available is on the PTO shaft. Loosen either end of this and correct the error (i.e make the broadcast station read properly on the counter holding the PTO shaft whilst turning the Kcs dial).
Piece of cake.

Date: Wed, 15 Nov 2000 04:29:35 -0800 (PST)
From: Tom Marcotte <courir26 'at' yahoo.com>
Subject: Re: [R-390] Cosmos PTO question

----- Original Message -----
> What is the coil inside the Cosmos PTO that is beside the end-point adjust
> coil? It looks to be in series with the end-point adjust coil. It seems
> as if it could be used as a coarse-adjustment for the end point, but I have
> not heard anyone mention it before. I only have two turns on the end#point
> adjust coil, and hate to remove one of those which would normally be
> the recommended adjustment.
>
> The second coil is the same diameter as the end-point adjust coil, except
> that it has three turns on it. It is pictured here -
> http://www.knology.net/~wewilson/images/CosmosPTO.jpg .

(This picture is no longer available, so I’m embedding mine, Larry Haney)



The end point adjust coil is lower left, and the other coil sits above and to the right, on the end of the metal sleeve that it fits into.

--- Walter Wilson <wewilson 'at' knology.net> wrote:

>-After a few replies and re-reading Tom Marcotte's article on the Cosmos PTO,
>-I see that the "extra" coil is part of the Cosmos corrector stack design. Now my
>-only question is this: I have only two turns on the end-point adjust coil, and
>-the spread is about 990KC. Do I really remove a turn from this coil and take it
>-down to only 1 turn?

You would remove one turn from the end point coil. This will move the endpoint quite a bit, enabling you to then use the adjusting screw to nail it.

Date: Wed, 15 Nov 2000 07:49:32 -0800 (PST)
From: Tom Marcotte <courir26 'at' yahoo.com>
Subject: Re: [R-390] Cosmos PTO

Good question! The article says to try the screw first, and if you can't achieve the 1000 kcs in ten turns, THEN remove the turn. Thanks for the heads up.

Date: Wed, 4 Sep 2002 14:39:06 -0700 (PDT)
From: "Tom M." <courir26 'at' yahoo.com>
Subject: Re: [R-390] Cosmos PTO question

Yes, the Cosmos has two caps, one for linearity and one for endpoint. When looking at the front of the PTO, the cap to the left gives access to linearity. Behind the transformer you'll find the cap on the right. Under this cap will be a screw that adjusts endpoint. You do this one first, however 11 kcs will require removal of a turn from the endpoint adjustment coil. This will require opening of the PTO to get at the coil. Last time I did this I just made a new coil with one less turn and replaced the old one with the new. After removing a turn, the PTO should have new life and you'll be able to get 1000 kcs in ten turns. The thing will drift in a predictable direction (I'll avoid the use of words like "long" and "short" because this list has long and short word police, equally rabid about "their word" :-)

What I do is give the thing about 1000.5 to 1001 kcs in ten turns to avoid having to go back in there within the next 12 months. One extra kc should last you a few years, after which the thing should be right on the money (like a stopped watch I guess!). Linearity adjustment is a whole other project. You can pull down some instructions from Chuck Rippel's website.

Larry Haney - Chuck’s website is no longer online, but you can see it here in the archives: https://web.archive.org/web/20090204020515/http://www.r390a.com/. I found two articles about the Cosmos there. The one by Tom (shown next) and one by John Harvie at PTOS (archive.org).

Larry Haney: This next post of Tom’s is nearly the same as the article he wrote in ER magazine number 107, on 3/1998. But, a plus in the article in ER is it has a few drawings included that make it easier to follow. Links to it are at the end.

Date: Sun, 15 Jun 2014 04:11:52 -0700 (PDT)
From: "Tom M. via R-390" <r-390 ‘at’ mailman.qth.net>
Subject: Re: [R-390] R-390A Cosmos PTO has erratic linearity

This is an article I wrote about how to calibrate the Cosmos PTO. Take a look and see if you find any nuggets. Tom
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Calibration of The Cosmos Permeability Tuned Oscillator for the R-390A by Thomas Marcotte, P.E. N5OFF

This article will focus upon the calibration of the Cosmos permeability tuned oscillator (PTO) for both linearity and endpoint adjustments. Few devices have been so maligned or poorly understood than the Cosmos PTO employed in the R-390A HF receiver. This device has been mentioned in articles about the R-390A many times, as well as on several Internet mailing lists, often negatively. The features of endpoint and linearity adjustments for this PTO have often been misunderstood, leading one to suspect it may be a poor device. This article will attempt to convince that the Cosmos PTO is worthy of service in the R-390A when adjusted properly.

Collins designed and built the first R-390A receivers utilizing its own 70H#12 PTO. This PTO covers a frequency range of 3.455 Kcs to 2.455 Kcs in ten clockwise turns. It is a robust device constructed of the highest quality materials, including an encapsulated main coil, sturdy compensating stack, and a temperature controlled oven.

The R-390A receiver was produced by many manufacturers other than Collins. These manufacturers were at liberty to employ the PTO's of suppliers other than Collins, as long as their performance met the specification MIL-R-13947. Consequently, PTO's employed in the R-390A were supplied by many other manufacturers including Motorola, Progresstron, Dubrow, Cosmos and Raytheon. Of all PTO types, the Cosmos seems to be the most common. Electronics Assistance Corporation used these PTO's exclusively in its production run of 11,000 R-390A's around 1967.

Cosmos Industries was a New York manufacturer of radio equipment located at 31-28 Queens Boulevard, Long Island. Among its products was the well known Cosmophone HF-SSB transceiver. The improvements made in the Cosmos PTO over the original Collins device were designed by Lewis Metzger and Harold Goodman, both instrumental in the development of the Cosmophone. They received US patent number 3,098,989 in July, 1963 for their idea and working model of a PTO that could be linearized with external adjustments, unlike the Collins PTO.

Anyone who has ever worked on an R-390A PTO soon finds out that there are two important adjustments that can be made. The first is that the PTO must be adjusted such that its output is exactly 1000 Kcs in ten turns. This is commonly referred to as the endpoint adjustment, and is as far as most users will go in PTO calibration. Endpoint adjustment is important as it not only affects dial calibration, but can also compromise front end track tuning on the lower bands. The second important adjustment is linearity. If one were to graph the ideal PTO output frequency versus the shaft position in number of turns, the graph would make a straight line. This was the goal of Collins Radio in all of its designs of the era, including the 75A, 32V and all of the later models. Art Collins wanted a linear output, and that was that. The Collins PTO was famous for being able to achieve this goal, as well it had to, because the inherently linear Veeder-Root counter of the R-390A exposed nonlinear PTOs with errors as low as 0.1 Kcs.

All PTO's employed in R-390A service have an endpoint adjustment screw. This screw is typically located underneath a sealed screw hole behind the PTO' s transformer can. As a PTO ages, its output will typically decrease, i.e., it will have an output of less than 1000 Kcs in ten turns. To remedy this, the endpoint adjustment screw must be turned (usually clockwise) until the PTO's output is increased to exactly 1000 Kcs in ten turns. The turning of this screw moves a tuning core into a second coil in the PTO to make the adjustment. PTO's of the Collins design will have two inductor coils, a main coil and an endpoint adjustment coil.

Adjustment of the PTO's linearity is another matter entirely. In the Collins PTO, the company employed an internal corrector stack which accomplished this task. This stack is constructed from a set of adjustable shims upon which a cam follower rides. As the PTO shaft is turned, the main tuning slug is advanced axially on a lead screw, and the cam follower is simultaneously advanced on the corrector stack. Naturally, advancement of the main slug on the lead screw is exactly linear, but unfortunately the coil and powdered iron tuning slug do not usually cooperate in linear fashion. The cam follower mechanism allows the tuning slug to either increase or decrease the overall rate of advancement on the lead screw by imposing a slight twist of the tuning slug. This increase or decrease in tuning rate is determined by the shape of the corrector stack and is what accomplishes the linearity correction. If a graph were made of the nonlinear response of the PTO, it might look very much like the profile of the Collins corrector stack when properly adjusted.

Linearity correction is necessary because it is virtually impossible to wind the main tuning coil and match it with an iron slug for an overall linear output. The only problem with the Collins design is that the corrector stack is inside the PTO cover. Naturally, adjustments must be done with the cover off, but unfortunately, replacement of the cover influences the adjustment requiring multiple attempts and no shortage of frustration. Metzger and Goodman solved this problem by improving the Collins PTO design. The Cosmos endpoint adjustment is similar to the Collins adjustment, however the real innovation is found in their external adjustment for linearity. This is the most misunderstood feature of the Cosmos PTO.

Upon careful examination of the Cosmos PTO, one will find the endpoint adjustment in its usual location as described above. To the left of the endpoint screw hole will be found an additional screw cover. Underneath this second screw cover will be found a series of very small screws. During clockwise rotation of the PTO shaft, this series of screws passes underneath this window from left to right. One screw will pass with every 90 degree turn (25 Kcs) of the PTO shaft. It is this series of screws that are used to adjust linearity of the Cosmos PTO.

The Cosmos PTO has three inductor coils instead of two employed by Collins. There is the familiar main tuning coil, an endpoint adjustment coil, and a third coil that is part of the linearizing device. Like the endpoint coil, the linearizing coil is in series with the others. The inductance change of the corrector coil is controlled by a core which goes in or out as the PTO is rotated through its ten turns.

To help visualize the corrector mechanism, picture if you will a Teflon disk laid onto the front face of the PTO. This disk acts as a cam. A cam follower contacts the slug of the third coil. The corrector disk rotates through a reduction drive as the PTO is advanced its ten turns. Under this disk is a series of screws which are laid out in a staggered fashion all along its circumference, forming a circle. The flat heads of the screws, which are adjusted to varying heights in close proximity to their neighboring screw, make up a (typically uneven) surface upon which the flexible Teflon disk rests. As the screws are adjusted in or out, the Teflon disk (formerly and initially flat) is shaped into a wavy surface (a cam) upon which a cam follower rides. You've seen the kiddy motorcycle rides at the carnival where the miniature vehicles go round and round, and also make a gentle up/down motion on the wavy surface of the merry-go-round floor. It is this slight vertical displacement of the vehicles that is analogous to the in/out motion of the core in the compensating coil.

<u>Calibration of the PTO</u>

Note: One should refer to the R-390A service manual before attempting to service the radio.

The two things needed to calibrate the PTO at 25 Kcs points are 1) an accurate means of measuring frequency, and 2) an accurate means of turning the PTO shaft exactly 90 degrees at a time. The author uses a frequency counter to measure the PTO output, and the Veeder-Root counter in the radio to measure the turns of the PTO. When using the radio's counter to measure turns, take the time to tape exposed 120 VAC power and fuse connections to prevent electrical shock while performing the more than 40 PTO remove/install maneuvers. The frequency counter is connected directly to the output cable of the PTO. A handy crossover connector from the PTO fitting to BNC can be found on the back bulkhead of the radio. Simply borrow the adapter that is present at the IF output jack. There are many alternatives to using the radio frame to measure turns, including using a sacrificial R-392 frame (credit Wally Chambers, K5OP), and various calibrated knobs.

Setting the endpoint on a Cosmos PTO is similar to the Collins PTOs. Test the PTO to see how many turns it takes to achieve an output starting at 3455 Kcs and ending at 2455 Kcs. Most aged PTO's that have not been recalibrated will typically require an additional 1-15 Kcs past the ten turn mark to achieve the proper range. To bring it back to 1000 Kcs output in ten turns, adjust the endpoint screw (usually clockwise). If the proper output cannot be achieved within the adjustment range of the endpoint screw, one must open the PTO and remove one turn from the endpoint adjusting coil. This change in overall inductance of the coil will bring the endpoint back 7 Kcs or so. Once this is accomplished, setting the endpoint can usually be achieved. While the PTO is open, the lead screw and bearing can be lubricated. The author usually takes this opportunity to bake an open PTO in an oven at 150F for several hours to dry it out and regenerate the desiccant. Perform the calibration only after baking, and keep the PTO in a zip lock bag if you plan to leave the adjustment window screws open for an extended length of time.

To enable linearization, the author finds it best to set the desired point on the Veeder-Root counter, and then physically uncouple the PTO from its coupler, tilting it up to access the adjustment screws. The screws are very small, and this technique will make insertion of the screwdriver onto the screw head true with minimal fuss. The steps for checking a calibration point are as follows:

1. set the Veeder-Root Counter to the desired calibration point (ex: 000).
2. note the frequency output and error, and record both on a calibration chart (ex: 3456 kcs, +1 kcs error). An example calibration chart will be developed below.
3. uncouple the PTO and tilt it up to access the adjustment screw (note this may jostle the output reading a bit, don't worry about that).
4. adjust the screw to remove the error (ex: -1 kcs, regardless of present reading which may have been jostled due to PTO uncoupling maneuver).
5. re-couple the PTO, and go to step one, adding 25 kcs to the Veeder-Root counter reading.

When setting the 25 Kcs calibration points, it is extremely important that the screw being adjusted is directly lined up behind the adjustment window. This may be accomplished by simply rotating the PTO shaft until the nearest screw is lined up exactly with the window. The reason this is so important is that the cam follower which rides on the compensating cam is directly behind this window, and will thus be directly under this screw at this point. If this caveat is not followed, adjustment can still be made, but there will be interaction between the point that one is attempting to adjust, and its neighboring points. This will yield poor results and will be very frustrating. Be advised that if the screw being adjusted is directly behind the window, the PTO position may not yield an exact 25 Kcs calibration point on the dial, e.g. 000, 025, 050, etc. This is not a real problem, but it may be necessary to shift the starting point of the 25 Kcs check points by 5, 10, or 15 Kcs up or down. Simply remember that the PTO has an output of 3455 Kcs at dial indication 000, and 2455 Kcs at dial indication +000. Armed with this information, one can make a spreadsheet calibration chart for all 40 calibration points in 25 Kcs increments. An example chart might look like this:

Frequency (Kcs)	Veeder-Root Counter	Error (Kcs)
3465	-010	
3440	015	
3415	040	
3390	065	

And so on . . . for 40 to 42 calibration points

The above example is for a PTO that has the nearest linearity alignment screw falling at a frequency of 3465 Kcs on the frequency counter. This corresponds to a starting point on the Veeder-Root counter of -010. Note that this starting point is not on an even 25 Kcs point, but that is OK as it is most important to start with the nearest screw directly lined up with the adjustment slug at the center of the window. To complete the chart, subtract 25 Kcs from the frequency and add 25 units to the Veeder-Root counter for each point out to 2455 Kcs. Each screw will have an adjustment range of about 5 Kcs +/-. Clockwise rotation of the screws will reduce the PTO's frequency output at a given checkpoint. One should avoid adjusting the screws to near their full clockwise position as this will cause excessive drag in the PTO.

Advanced Procedure for the Stout Hearted

To remedy problems with excessive drag due to adjustment screws reaching their clockwise limits, back all 40+ screws out to their counterclockwise stops, and then turn each screw one turn clockwise. This will give the cam an initially flat position. Start PTO calibration at the point nearest 3455 Kcs moving up the dial toward 2455 Kcs (+000 on the Veeder-Root counter).

Remember to check each calibration point against the frequencies on the calibration check chart (it is not hard to get 5 Kcs off). Some check points may require a touch-up calibration after completion of the first pass. This will be especially true if the PTO calibration was re-started with the cam in the initial flat position as described above. Extreme adjustment changes (5 Kcs) at any given point may cause output changes at neighboring points. These can be worked out with multiple checks and adjustments at problem checkpoints.

With this linearization procedure, it is possible to obtain checkpoint accuracies of +/- .100 Kcs with an initial dial calibration at 000 using the crystal calibrator. This greatly exceeds the specifications listed in MIL-R#13947B which require a +/- .300 Kcs with a dial calibration at the nearest 100 Kcs check point using the crystal calibrator.

In conclusion, the reader should be left with these points.
- the Cosmos PTO can be calibrated for both endpoint and linearity.
- calibration can be done at 25 Kcs points, typically exceeding military specifications.

References:
Military Specification MIL-R-13947B, "RADIO RECEIVER R-390()/URR", 26 October 1960
TM 11-5820-358-35, "Field and Depot Maintenance Manual, Radio Receiver R-390A/URR", pp. 107-108.
"Serially Connected Course and Fine Inductors with Continuous Adjustment", U.S. Patent number 3,098,989 awarded to Metzger and Goodman, 23 July 1963
Also credit: Discussions with Wally Chambers, K5OP, Memphis, TN.

Tom first posted his excellent article above on our list forum on Thu, 16 Sep 1999 17:38:36 (PDT). Before that, he submitted this article to the ER magazine and it’s in issue number 107 of 3/1998.

It is a great write up and was reprinted shortly after that (with permission of ER) in Hallow State News Issue 45, Summer-Fall 1998 (part 1) and part 2 in issue 46. It’s titled 'CALIBRATION OF THE COSMOS PERMEABILITY TUNED OSCILLATOR FOR THE R-390A'. And, the article in ER and HSN have a few drawings included that make it easier to follow. Here are links to part 1 (in issue 45) and part 2 (in issue 46) in HSN:

https://www.navy-radio.com/manuals/hsn/hsn-issue%2045.pdf
https://www.navy-radio.com/manuals/hsn/hsn-issue%2046.pdf

Enjoy. Larry Haney