TRUING A FACTORY BOLT ACTION

By Jim Boatright

At its core, this is a "how to" article about truing factory-made bolt actions. It is also, however, a "why" and "why this way" article. We aim to increase, however slightly, the general level of knowledge in the rifle accuracy community and to stimulate healthy debate and further studies on the subject among gunsmiths and rifle shooters alike. We do not leave out critical details in the "how to" sections for reasons of "trade secrecy." That is an idea to which we are constitutionally opposed. We also discuss exactly why one particular technique is preferable to another. Because we believe that a complete logical understanding of this truing process is more important in the long run, we fully explain our rationale for each step as we go along. In fact, for the persevering reader, we present at the end of this article what could be considered a larger philosophical point to ponder that might encourage further accuracy studies.

INTRODUCTION

Truing a factory-made bolt action produces a relatively inexpensive principal component of a custom rifle that helps to convert that rifle into a much more accurate but equally usable alternative to a factory-built rifle. The complete action truing process described here is the same as what is meant by "blueprinting" an action. Unfortunately, incomplete or incorrect rifle action truing has given rifles built using this approach a historically poor reputation for accuracy improvement and a correspondingly poor resale value. The methods that we describe here can be implemented quickly enough and inexpensively enough that a gunsmith can ensure dramatic and worthwhile accuracy improvement without charging more for the work than the results justify. We have always charged $300 for the action truing work described herein (which just about doubles the cost of the factory bolt action). Because only a bare bolt assembly and receiver are needed for this procedure, and because all critical surfaces are going to be re-cut in this truing process anyway, a usable second-hand or even a set of mismatched parts can work out just as well as starting with a brand new action. The cost of the trued factory action should not even approach the cost of a new custom action (about $900 and up). Moreover, building-out the trued factory action into a finished rifle requires a similar amount of time as when using a custom action—because the barrel tenon dimensions and thread standards are known and invariant, this process does not necessitate any tedious measurements (except, of course, for headspace depth-gauge measurements). However, while the finished rifle should be almost as accurate as the equivalent custom rifle built around a custom action would be, the blueprinted rifle can retain exactly its factory appearance, if desired. The contradictory requirements of equally satisfying results at a lower cost, as well as the historically poor resale value of rifles built on trued factory actions and the high cost in gunsmith time required to true-up actions by earlier techniques, have no doubt convinced many accuracy gunsmiths that it is not feasible to true a factory bolt action.

To the contrary, I believe that for an important subset of the available factory bolt actions (i.e., the Remington 700 family of actions) a valuable and economical truing procedure can be performed. Truing, or blueprinting, a factory-made bolt action is a series of minimum metal removing steps and one metal adding step that will produce a coaxial, tight and square action when performed correctly and in the correct order. In this article, we will illustrate the process by truing a Remington 700 action. Any new or used member of the Model 700 family of chrome-moly steel actions would be a good candidate for this type of truing, even the centerfire Model 40X. We have found the heat-treating of Remington's chrome-moly actions to be quite consistent, at least as indicated by post-manufacturing machinability. We recommend that only these particular actions be trued using these techniques. Although we have experimentally trued Winchester Model 70 actions, stainless-steel Remington Model 700's and other types of actions using this technique, we do not recommend that other gunsmiths try them. On occasion, we have encountered very tough or hard receivers that have prematurely dulled our tooling.

EXPECTED RESULTS

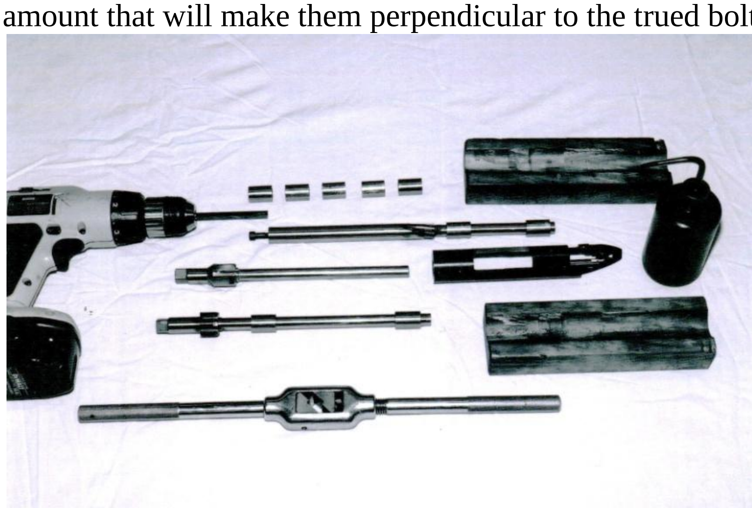
When we build a completed rifle on one of these trued actions, we guarantee and demonstrate ¼-inch five-shot grouping capability at 100-yards for a varmint-weight rifle chambered for an accurate cartridge such as the 223 Ackley Improved, 6mm BR Norma, 308 Winchester or the 6.5mm-284 Norma, just to name a few. These are first good 5-shot groups after barrel break-in. We use a "one-shot-and-clean" barrel break-in procedure for the first few shots and then progress to two shots (etc.) as the evidence of copper fouling indicates. These early shots are also used to zero the scope. We break-in the barrel until we can get a good 5-shot group before copper fouling causes a thrown shot. With further break-in and load development, we can sometimes fire a "bragging group" of around 0.200-inch. However, this is still a little less than competitive benchrest accuracy in similar conditions. The best barrel breaking-in 5-shot group I have seen in my 105-yard indoor range was measured at 0.050-inch from a 17-pound "thousand yard" BR rifle in 6.5/284 Norma. [That customer later called back to ask if his initial 3/8-inch groups at 300 yards were any good!] Lighter-barreled or heavier-recoiling hunting chamberings are guaranteed to group three shots into 3/8-inch. That is not to say that these rifles are not as accurate as their heavier brethren, but it is more trouble to shoot them for accuracy and the application does not demand it. We should mention here that this level of accuracy is obtainable only in a fully custom-built rifle put together with great care and using the finest barrel blank obtainable. In other words, to achieve these results, you have to do everything else right too. While we did not develop any of the tooling or techniques described here, we do perhaps combine them in a new and innovative way. We are indebted to Greg Tannell of Gre-Tan Rifles and to Jim Borden of Borden Rifles (as well as to many others) for pioneering each of these action-truing techniques and then generously sharing them with us all. We stand on the shoulders of giants.

RELEVANT OBSERVATIONS

There are various deviations from ideal trueness that one should expect to encounter with any factory-made bolt action prior to its being trued. These observations are based on several years of experience accurizing many types and many different makes of rifles and are not intended to demean the quality of the factory bolt action in any way. First, the inside diameter (ID) surfaces of the boltway are several thousandths oversized. The boltway itself is usually tapered (larger at the front for some reason—like in order to accommodate crooked chambers) and curved (banana-shaped, probably as an artifact of heat-treating). Short actions tend to be more curved than long actions. Furthermore, the front receiver threads are almost always tapped visibly skewed off-axis. Also, the outside surfaces of the receiver are heavily polished and should not be expected to be mechanically true for any purpose. [We do not true these surfaces, but merely take this into account when bedding the action or mounting scope bases.] As to the bolt body, it is under-sized and banana-shaped with four to eight thousandths of an inch vertical clearance (slop) at the rear of the bolt when the bolt is locked. Only a portion of the lower bolt lug is seated when the back of the bolt is pushed upward by the sear any time the striker is cocked. As most people are aware, the bolt lugs do not bear evenly upon their seats in the factory receiver. However, this is a moot point until excess bolt slop has been eliminated. Also, the bolt face is not particularly square with anything, nor is the firing pin hole in the bolt face going to be held centered in the front receiver ring. We believe that bolt slop leads directly to huge vertical-plane transverse vibrations in the rifle barrel during firing as the bolt body moves to try to seat its top lug during the firing cycle, urged on by maybe four tons of bolt thrust. These vibrations reach the muzzle well before any bullet can. They propagate with a velocity of just over 5,000 meters per second in the barrel steel, compared to a muzzle speed of maybe 1,000 mps for the bullet. We expect that these and other non-ideal conditions exist for valid economic reasons in mass-produced factory-made bolt actions, but what is surprising is how well these strong, cheap, safe and reliable hunting rifles actually work in producing "minute of moose" accuracy (1.5 to 3.0-inch groups at typical hunting ranges of 75 to 125-yards).

THEORY OF TRUING TECHNIQUE

After deliberating on the matter, we decided to true the inside and frontal aspects of the front receiver ring to the axis of the boltway that must have first been trued into a cylinder of constant, minimally-oversized, inside diameter (ID) about a straight central axis. Thus, the first step must be an align-boring or piloted reaming of the inside of the boltway. The threads in the front receiver ring will then be enlarged by the smallest amount that will make them concentric with the axis of the trued boltway. The recoil seats for the bolt lugs and the front face of the receiver will be faced off by the least amount that will make them perpendicular to the trued boltway axis. The bolt body will

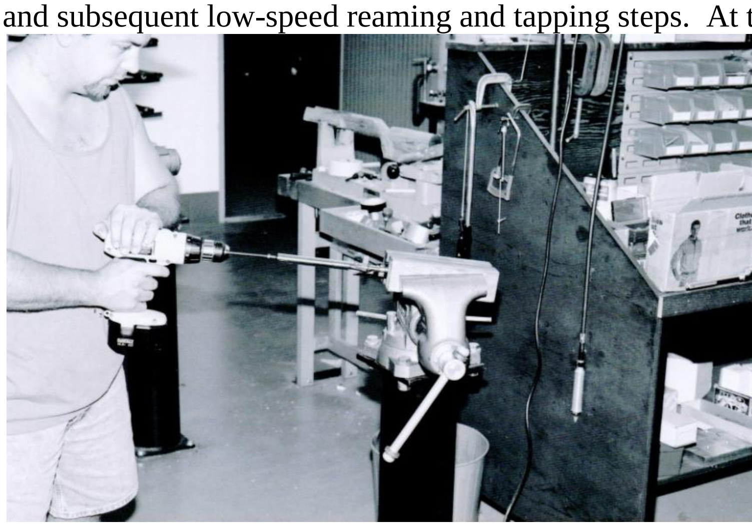


be sleeved, front and rear, with two stainless steel rings of an outside diameter (OD) to match the ID of the trued boltway. The axis of the two installed bolt sleeves is constrained by its set-up in the lathe to pass through the center of the firing pin hole in the bolt face. The critical rear faces of the bolt locking lugs are faced off by the minimum amount to make them perpendicular to the axis of the bolt sleeves. The bolt face and bolt nose are similarly squared to this axis as well. The close fit of the sleeved bolt body inside the trued boltway of the receiver will henceforth keep all critical surfaces correctly aligned. Any loss of action strength due to removing metal from the ID of the front receiver ring is essentially offset by having the barrel tenon OD larger by the same amount. Photo #1 shows a layout of the equipment that we use to true the receiver. [We now use a hand-turned bolt-way reamer made by Dave Manson instead of the motor-driven tool shown.]

STEP 1: RECEIVER WORK

The first step in truing the receiver is to ream the boltway to a fixed oversize ID so that the usual variation in ID and curvature in the axis of the boltway are removed. We use a 0.7050-inch cutting diameter three-way piloted reamer powered by a hand-held drill motor to do this. [Since this was written, we have found a better action reaming technique. Dave Manson made for us a hand-turned, left-hand spiral, right-hand cutting 0.7050-inch cutting diameter, tool steel, piloted reamer that is a joy to use with a large tap wrench.] The two pilot bushings fitted on the long, half-inch diameter front shank of the reamer provide tool guidance ahead of the cutting blades. This tool also pilots on the full-diameter shank portion behind the reamer blades. Typically, and as is the case with this particular receiver, the front ring of the receiver will just accept a 0.7035-inch outside diameter (OD) pilot bushing while the rear ring needs a 0.7025-inch pilot bushing. You will need a full set of one each of these cylindrical, one-inch long pilot bushings ranging in OD from 0.7015-inch through 0.7045-inch by half thousandths, plus the pair 0.7050-inch bushings that should come with the reamer set. Do not use any tapered pilot bushings that may sometimes be supplied with a boltway reamer.

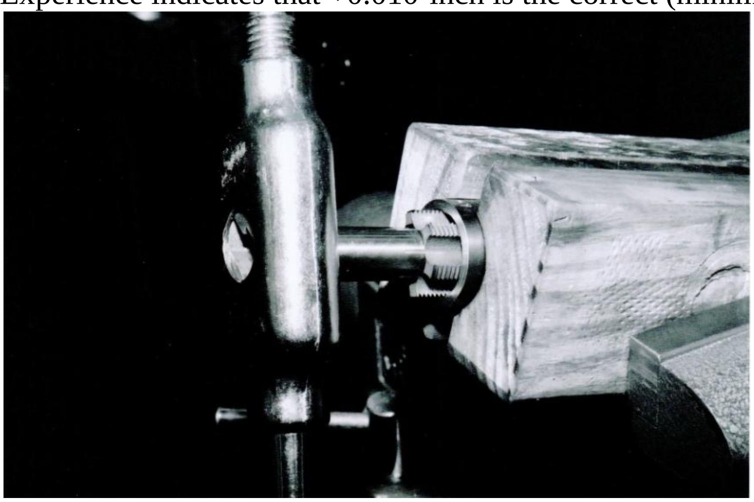
Holding the receiver in shop-made fitted wooden jaws in a sturdy shop vise, we make the first reaming pass all the way through the action starting from the end where the factory boltway is the tightest. By starting at the tighter end, we can push the larger forward pilot from the action with the smaller rear pilot and not have to stop to remove the unused rear pilot when its work is done. We use old fashioned, dark tapping fluid to lubricate this and subsequent low-speed reaming and tapping steps. At this point, we usually switch to a pair of 0.7050-inch pilots and make a "clean-up pass" through the action from the other direction. This reverse pass reduces the reamer marks in the boltway and also reduces the hand de-burring that will be done later. [Photo #2 shows this reaming set-up].



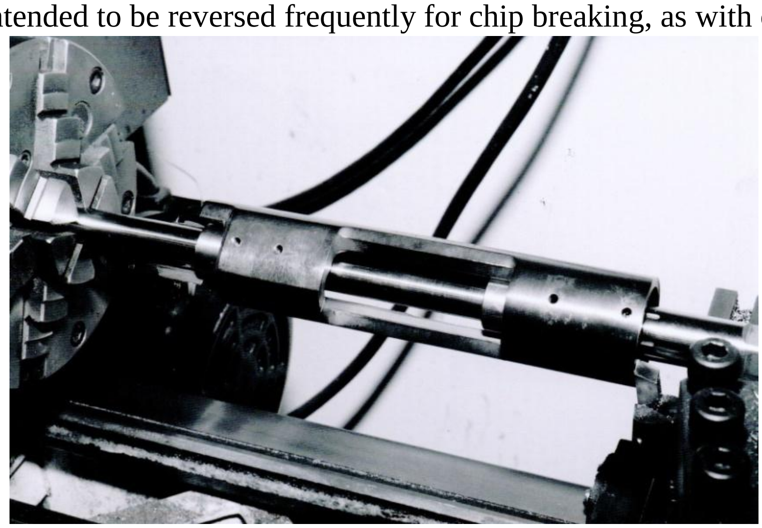
At this point in the truing process, the boltway surfaces are all freshly reamer-cut and define a straight cylinder of 0.7050-inches diameter that we will use in following steps ***to define the mechanical axis of the receiver***. We should caution that this reaming step is necessary even if the boltway of an action should check out at, say, 0.7020-inches at both ends. One reason is that most factory actions are slightly warped, probably by heat-treating after final machining: the reaming step is necessary to straighten the axis of the bore. Another reason is that we may very likely need the bolt clearance obtained by reaming to 0.7050-inch ID later when it comes to fitting the sleeved bolt into the boltway. This is because the bolt bodies themselves are also warped more or less into a banana shape.

Now, we will use another reamer to cut the inside of the front receiver ring to make it coaxial with the boltway and 0.010-inch oversize. This reamer is hand turned and is piloted using the same two 0.7050-inch pilots we were just using for the second boltway reaming pass above. We proceed with this reaming until the facing cutters on the front of this reamer have minimally re-cut (squared-up) the recoil lug seats inside the front ring of the receiver. A little layout dye applied to these recoil seats will aid in determining when this step has been completed.

Using the same two 0.7050-inch pilot bushings, we now switch to a piloted hand tap to re-cut the 60-degree, V-form threads of the front receiver ring to make them straight, concentric and 0.010-inch oversize to 1.0725-inch by 16 Threads Per Inch (TPI). Experience indicates that +0.010-inch is the correct (minimum) amount needed to align



the threads in these receivers. We had a similar piloted tap made at +0.015-inch, but only used it once in over 200 applications. The piloted tap must be rather carefully started ***in-phase*** with what remains of the original factory threads. [Photo #3 shows the set-up for this step]. Note that this strongly (doubly) piloted tap does not, and indeed cannot, merely follow the miss-aligned and eccentric factory threads as would an un-piloted tap. This marvelous tool cuts the new threads ***coaxial*** with the newly trued boltway. Also, note that this tap is not intended to be reversed frequently for chip breaking, as with ordinary hand taps. When

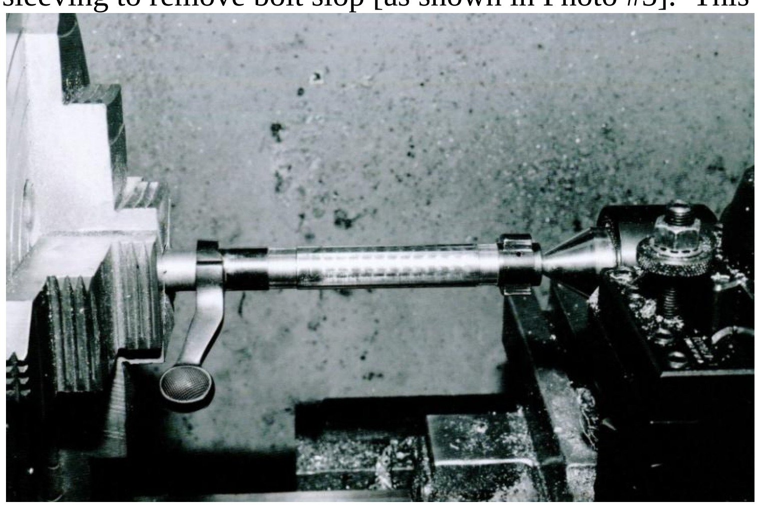


all of the factory threads have been re-cut, the tap itself will be well down inside the front ring of the receiver by the time the tap becomes too tight to turn by hand. At this point, the piloted tap can be used as a mandrel to hold the receiver squarely in any available lathe for minimally facing off the front surface of the receiver ring. [Photo #4 shows this set-up in a lathe for this last machining step on the receiver]. After backing out the tap/mandrel, the feather thread at the front of the receiver is removed using a sharp scraper/deburring tool. Except for hand deburring throughout and polishing of the feed rails and feed ramps, this completes all truing work on the receiver. Note that the factory barrel and recoil lug cannot be re-installed with the new diameter front threads. This is actually a good thing.

We have tried other techniques for receiver truing in the past. The only other technique which we believe can be as exactingly correct as the technique detailed here would be "single pointing" the front threads, recoil seats and face of the receiver. Done correctly, this requires a tedious set-up of the receiver in an eight-way adjustable holding jig which is itself held in a lathe chuck. We must then pick up the inside threads several times as they are being trued which is also fairly tedious. The advantage of being able to stop cutting just as soon as concentric threads are obtained is more than offset by the hours of extra set-up, machining and measuring time required both for action truing and for subsequent barrel fitting. Keep in mind when deciding to true the front ring of the receiver using single-point lathe work that you will need accurately to measure or gauge the non-standard V-threads you will making so that you can later cut the correct tenon diameter on the new barrel. Proper set-up and execution of this alternate technique is not only tedious and time consuming (in other words, expensive), but requires a better lathe than some of the old ones we own that have worn lead screws.

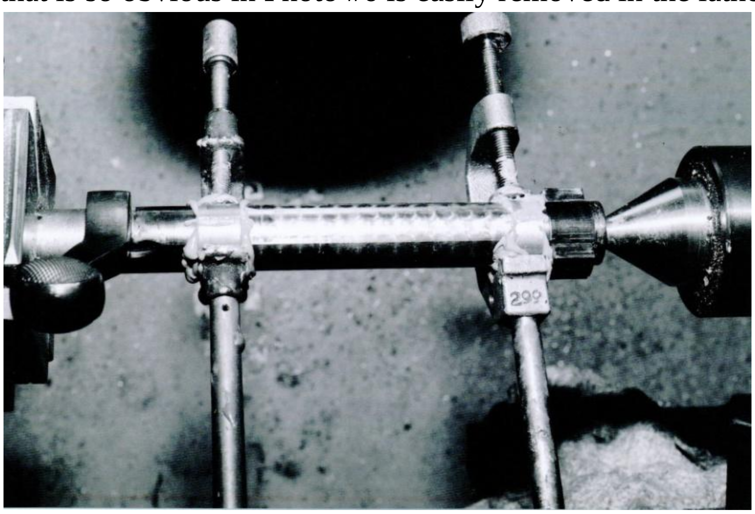
STEP 2: WORK ON THE BOLT

We now switch our attention to the bolt. It should be set-up in a lathe for truing and sleeving to remove bolt slop [as shown in Photo #5]. This is the one step where we *add* metal to the action in the truing process. The rear of the bolt is held in a four-jaw chuck using a shop-made threaded mandrel. The bolt-engaging threads of the mandrel used for holding the rear of the bolt body are purposely made to be a loose fit so that the orientation of the bolt can be slightly adjusted without stressing the bolt. The front of the bolt is held by the tailstock using a live center and a shop-made button that allows piloting off the firing pin hole in the bolt face without any possibility of damaging it. The four-jaw chuck is usually adjusted to minimize run out at about the midpoint along the bolt body. Each bolt is different, and a particular example may require a different alignment compromise. Hand turning the lathe chuck with the drive in neutral will allow careful observation and accurate indicating of the amount of wobble at different points along the bolt body. We find it useful to chuck the bolt so that the plane of the bolt recoil lugs is aligned with jaws #1 and #3. We use a test indicator to measure run out in the more critical plane of the



recoil lugs. Once the best new ***permanent alignment*** of the bolt body has been decided, the bolt body is undercut to 0.650-inch diameter in two areas; behind the recoil lugs and ahead of the root of the bolt handle. The front undercut is 1/4-inch wide starting just behind the stress-relieving radius at the base of the rear face of each bolt-locking lug. The rear undercut is made about 3/8-inch wide starting about a half inch in front of the bolt handle. Inspection of the newly-reamed boltway surfaces will indicate the locations of the critical lower bearing surfaces, and temporary marks on the bolt body should show the edges of the two portions of the bolt body that are concealed by the receiver bridges when the bolt is closed and locked.

Previously prepared stainless steel D-shaped sleeves are then epoxied into place, clamped and cured overnight with heat added via an incandescent lamp. All this bolt work must be done *without disturbing the set-up in the lathe*. The sleeves are made up ahead of time from old stainless barrels by turning a couple of inches of the outside to 0.750-inches OD, boring to 0.680-inches ID, cutting off to 1/4 and 3/8 -inch widths, and then slitting the rings using a hack saw. After trial fitting and thoroughly de-greasing the parts, we carefully mix up a little JB Weld epoxy for use as the adhesive agent. [We now use Devcon 10760 Titanium epoxy putty to adhere the bolt sleeves.] The excess adhesive that is so obvious in Photo #6 is easily removed in the lathe. After curing overnight, the two sleeves are turned to 0.7049-inch OD and the rear faces of the recoil lugs are minimally faced off square, being careful not to touch the radius at the bottom of the lugs. Then, if the geometry of your steady-rest rollers permits, you can run them directly upon the front sleeve. With some lathes like our Nardini, we install a sacrificial sleeve over the bolt lugs, held in place with a setscrew and then turned true, for the steady rest to run upon. In either case, the bolt nose and bolt face are trued by removal of the least possible amount of metal as shown in Photo #7. Use great care in facing off the rear faces of the bolt locking lugs. Select a left-side facing tool-bit having a generous 0.060-inch tip radius, and fair the facing cut into the factory fillet at the bottoms of the lugs.

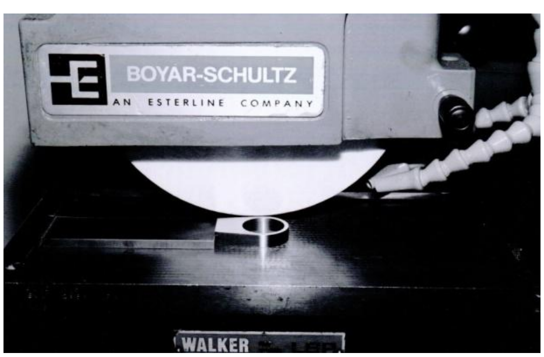


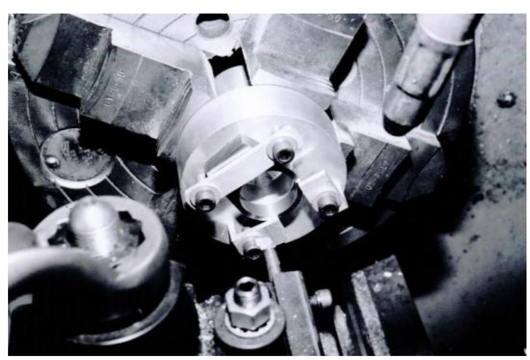
The sleeved bolt body is then trial-fitted into the trued receiver, and primary extraction cam-out is checked. We do not lap the recoil lugs as they are now machined into perfect engagement. The sharp edges of all the freshly cut bolt surfaces are hand radiused with fine files or medium-grit stones. A tiny bevel is put on the front edge of the firing pin hole to minimize cutting out discs of primer cup material (primer blanking) during firing. The 90-degree and 270-degree quadrants of the front bolt sleeve (with respect to the plane of the recoil lugs) are filed down by hand to match the original diameter of the bolt body, and the sleeves are polished for smooth running in the action. This creates the “Borden Bumps” which allow the bolt to cycle freely, yet lock up with no perceptible play.

At this point, we are done with the truing and machine work on the bolt body unless bolt face or extractor modifications are required. [The completed receiver and bolt body are shown in Photo #8]. Some may prefer to solder the bolt sleeves into place rather than fool with an epoxy product. We decided never to risk heating a strength-critical, heat-treated part, and these bolts also appear to be an assemblage of parts that have already been hard-soldered together. Please do not seriously consider omitting this bolt sleeving step or leaving out the front sleeve. We have seen two rifles go from ½ to ¾-inch grouping to under ¼-inch grouping when only the bolt-sleeving step was completed. Achieving this level of accuracy is why we are doing this in the first place. Some may argue that the front sleeve, especially, might impede bolt cycling on a “serious” rifle being used in adverse field conditions. With proper relieving and polishing of the sleeves, we do not believe this would ever present a problem. But we do not recommend truing any action to be used in a short-range hunting rifle. Anyway, we would prefer our customers select a heavy caliber double rifle or perhaps a 416 Rigby Mauser for close work on dangerous game. We confidently recommend a trued Remington 700 action as the basis for a reliable and accurate tactical rifle.

STEP 3: COMPLETION OF WORK

In the case of our example Remington 700 action, we will re-install the current style Remington extractor. However, if we had to alter the bolt face ID for some reason, we





would install a Sako-style extractor. We usually install a weaker ejector spring (or none at all) or even block-off the ejector hole depending on the type of rifle being built. For accuracy, we prefer to retrofit an older-style Remington or aftermarket bolt shroud and cocking piece parts (without the new ISS striker lock) so that we can install a matching older-style Tubb Speedlock system with its factory-strength silicon-chrome striker spring. We will also install a Tubb 3/8-inch thick stainless steel recoil lug that we have surface-ground true for parallelism [as shown in Photo #9] and then hand-lapped at room temperature into as perfect parallelism as we can measure with a good Mitutoyo micrometer. [David Tubb's recoil lugs no longer need the surface grinding step.]

The recoil lug is then lathe-bored oversize to 1.0700-inch ID [Photo #10] to match the tenon diameter of the new barrel closely. The difficulty with trying to grind the two faces of the recoil lug accurately parallel using a surface grinder or any other machine is that you must make slow, shallow cuts using lots of cooling and using a really true wheel. The problem is to avoid letting the "thin side" of the recoil lug get much warmer than the "thick side," which will cause different thermal expansions during the grinding. The more heated, and expanded, material will mic a lot thinner after cooling down to room temperature. Alternatively, hand-lapping and frequent careful measuring can be used to parallel this part with less investment in machinery and more in elbow grease. An improved trigger/safety unit will also be installed.

When properly barreled, stocked, bedded and scope-mounted, these trued factory-built actions reliably produce sub-quarter inch five shot groups after proper barrel break-in and using reasonably good hand-loaded ammunition. We like to build-out these actions into complete rifles and test them in our indoor 105-yard instrumented test range attached to our shop. Photo #11 shows a single five-shot group recently fired (in 2003) by two different shooters using two slightly different loads in 6.5mm-284 Norma. It was fired using our prototype tactical rifle [Photo # 12] made by blueprinting a Remington 25-06 Sendero and converting it to 6.5-284 Norma using a stainless steel Krieger 8.5-inch twist "Sendero profile" barrel. This rifle is capable of shooting 5-shot groups measuring well under one in inch extreme spread on our 420-yard outside test range (ridge-to-ridge, 140-feet above a small creek on our place).

CONCLUSIONS

We believe that the drastic reduction in static stress levels in the metal of the receiver and in the barrel tenon is a key factor in the consistent success of this procedure as an accuracy enhancement technique. We noticed years ago that when we screw in a replacement barrel into the custom action of one of our benchrest competition guns, it hand turns easily and then shoulders up suddenly with a solid "thunk." Very little additional tightening torque is needed or applied. We expect to experience this same phenomenon when installing a barrel into one of these trued Remington 700 actions with a trued Tubb recoil lug in place (but we do use a bit more barrel torque than with the BR rifle just to lock the recoil lug rotationally into place). In fact, if we started routinely pinning the recoil lug to the receiver face, then we would install these barrels just as our BR barrels are—little more than hand tight. We compare this situation with the three-foot cheater handle that we routinely use on the action wrench to unscrew the factory barrel. We believe the great static bending stresses caused by installing the barrel into an off-axis tapped factory receiver with maybe 250 foot-pounds of torque will cause erratic pointing of the barrel from the receiver after the commotion of firing each shot has died out. This random pointing difference will then affect the placement of the next shot fired on the target.

Based upon our experiences barreling really true actions, both custom actions and trued factory actions, it seems to us that off-axis factory receiver threads are likely to have been the root cause of the barrel joint movement problems documented by Harold R. Vaughn in his valuable book, ***Rifle Accuracy Facts***. While we may or may not be correct in our theories of *why* these techniques work, we do believe that the accuracy of our results and the consistent production of these results indicate that *how* we true these actions is about right.

In conclusion, as a larger philosophical point, we believe that learning to *minimize the levels of static stress* in all parts of the rifle is one of the key accuracy lessons that we have discovered in perfecting this truing technique. By "static stress" we mean the anisotropic (not equal in all directions) forces applied to, or within, the parts of the rifle as it sits ready to fire. We are not referring to the (good) isotropic stresses built into the steel at the crystal-lattice level by proper alloying, carbon doping and heat-treating. Nor are we referring to the separable problems of dealing with, for example, the "dynamic stresses" occurring during the approximately 5 milliseconds from sear break to bullet exit that result in recoiling rifle motion and in barrel vibrations. These (bad) static stresses may be left over from some metal-forming operation (such as barrel or receiver straightening) or may arise during assembly of the rifle parts (as discussed above). They may be due to differential heating (e.g., a scope rigidly mounted to a warming receiver on two-piece bases) or simply due to supporting the weight of the barrel against the pull of gravity (think barrel-block bedding). In future articles, we shall address each of these types of static stress and the rifle designs that handle them.