17 – WHEEL TRUING AND REPAIR

ABOUT THIS CHAPTER

This chapter is about repairing wheels. It covers truing the wheels (adjusting spokes so that the rim is more round, centered, and wobbles less), replacing broken spokes and damaged nipples, and fixing minor rim damage. The chapter **WHEEL BUILDING AND RIM REPLACEMENT** is about replacing rims and building new wheels. That chapter does not include anything about truing wheels but refers to this chapter for that process.

GENERAL INFORMATION

TERMINOLOGY

Cross pattern: The pattern created by two sets of spokes in a hub flange that radiate in opposite directions on their way to the rim. If one clockwise radiating spoke crosses three counterclockwise radiating spokes from the same hub flange, then the wheel is said to have a "three-cross pattern."

Dish: The centering of the rim to the hub locknuts. Because the flanges of a rear hub may not be equidistant from the locknuts, a rim centered to the locknuts is not necessarily centered to the hub flanges. Viewed from the wheel's edge, this makes the wheel appear like a dish viewed from its edge.

Eyelet: A separate metal reinforcement that goes in the spoke nipple hole in the rim.

Hub: The mechanism at the center of the wheel that an axle rotates inside of and to which the spokes attach.

Hub flange: The disc on either end of the hub to which the spokes attach.

Interlace: If a spoke switches from crossing over spokes to crossing under the last spoke it crosses on the way to the rim, the switch from crossing over to crossing under is called an *interlace*.

Kgf: Stands for *kilograms of force*. This is a unit used to measure the tension of a spoke.

Nipple: The elongated nut that threads onto the threaded end of the spoke and attaches the spoke to the rim.

Radial bump: This is a radial error that deviates further from the center of the wheel than the rest of the rim.

Radial dip: This is a radial error that deviates closer to the center of the wheel than the rest of the rim.

Radial error: This is a deviation in the round of the rim. Radial errors are sometimes called "round errors."

Reading unit: A number that is read from a spoke-tension meter. The reading unit must be looked up on a chart specific to the spoke-tension tool being used to convert to kgf.

Rim: The metal hoop at the outer end of the spokes to which the rubber tire attaches. The word "rim" is sometimes misused to apply to the wheel, including the spokes and hub.

Rim beads: The two edges of the rim at the rim's outer perimeter.

Rim sidewall: The face of the rim that contacts the brake pads.

Spokes: The wires that go between the hub and the rim.

Spoke elbow: The end of the spoke that makes a 90° bend where the spoke goes through the hole in the hub flange.

Spoke head: The flattened disc at the end of the spoke elbow that keeps the spoke from pulling through the holes in the hub flange.

Spoke hole: The hole in the rim where the nipple comes out, although it would be better called the "nipple hole." With regard to the hub, the hole in the hub flange that the spoke goes through is also called the spoke hole.

PREREQUISITES

Wheel removal and installation

Before repairing a wheel, the wheel must be removed from the bike. See the **WHEEL REMOVAL, REPLACEMENT, AND INSTALLATION** chapter (page 18-6) if unsure about wheel removal and installation.

Tire removal and installation

Before repairing a wheel, the tire usually must be removed from the wheel. See the **TIRES AND TUBES** chapter (page 19-3) if unsure about tire removal and installation.

Freewheel removal and installation

To replace a broken spoke, it is necessary to remove the freewheel or freehub cogs. See the **FREEHUB MECHANISMS AND THREAD-ON FREEWHEELS** chapter for freewheel removal (page 25-9) and freehub-cog removal (page 25-15).

Hub adjustment

Before truing a wheel, the hub must be adjusted to have no free play when out of the bike. See the **LOOSE-BALL HUBS** chapter (page 12-12).

INDICATIONS

Symptoms indicating need of wheel repair

There are several reasons to repair wheels.

Truing is needed when the side-to-side wobble (lateral error) of the rim makes it difficult to adjust the brakes (to eliminate brake-pad rub) without compromising the brake adjustment. Truing might also be needed because the rim is out of round (radial error), causing difficulty with getting the brake pads set at one height that is not too high at one point and too low at another point. Another reason wheel truing might be needed is that the rim needs to be centered to the hub (dished). The symptoms that would lead to suspicion that the wheel needs dishing are that the bike has a tendency to pull to one side (particularly when riding with no hands) or that it is difficult to get the rim properly centered in the frame or fork. The symptoms indicating that the rim needs dishing can be caused by many things other than rim dish, but dish is one of the easiest causes to check for and correct, so it should be done first. See the troubleshooting section of this chapter (page 17-32) for other possible solutions when dishing a rim does not eliminate the symptom(s).

Replacing a broken spoke needs to be done whenever a spoke breaks. More importantly, a broken spoke indicates other problems. If spokes continue to break, it indicates that the life of the spokes is used up, and the wheel should be rebuilt or replaced.

Repairing minor rim damage is advisable when truing is unsuccessful in eliminating the lateral errors while maintaining proper spoke tension. There are severe limitations to what can be done about repairing damaged rims, so very often the ultimate repair is rim or wheel replacement.

Symptoms indicating need of wheel replacement or rebuilding

Either during the course of a wheel repair or even before the repair is attempted, symptoms might be experienced that indicate it would be better to replace or rebuild the wheel. These symptoms are:

> Multiple broken spokes, either all at once or one at a time over the last few hundred miles.
> Multiple corroded nipples that won't turn.
> Multiple damaged nipples (rounded-off flats).
> Dents or bends in the rim that cannot be adequately straightened by normal spoke adjustment and unbending techniques.

Cracks in the rim.
Severe rim-sidewall wear.

Maintenance cycles

There is not much routine maintenance to wheels other than repairing them when one of the above symptoms is experienced, but two things are very important. First, the key to wheel longevity is proper spoke tension. Proper tension promotes longer spoke life, long-lasting true, and longer rim life. Fortunately, another thing proper spoke tension promotes is stable spoke tension. Once tension is set right, it probably will not need regular attention. Unfortunately, only a minority of bicycle manufacturers and bike shops pay attention to this critical factor. Whenever assembling a bike or truing used wheels, check the spoke tension first.

The second form of wheel maintenance is nipple lubrication. The nipples are the little elongated nuts at the rim end of each spoke. These nipples are tightened or loosened, which is how the wheel is trued. In many climates, the nipples have a tendency to corrode solid even before the wheel needs to be trued the first time. The shop should put a drop of light oil that can penetrate at the top of each nipple so that it will soak down into the threads whenever general maintenance is done. The only exceptions to this are when it is known that the threads have been treated with a compound such as Wheelsmith Spoke Prep (a "lifetime" corrosion preventative) or when you know that the climate is so dry that rust and corrosion are not a problem.

TOOL CHOICES

Table 17-1 (page 17-3) covers all tools for the job. The preferred choices are in **bold**. A tool is preferred because of a balance of ease of use, quality, versatility, and economy. When more than one tool for one function is in **bold**, it means that several tools are required for different configurations of parts or that two or more tools are equally suitable for the job.

TIME AND DIFFICULTY

Truing a wheel is a 15–35 minute job of moderate-to-high difficulty. Replacing broken spokes, then truing the wheel, is a high-difficulty job that could take from 20–35 minutes. Repairing a damaged rim then truing the wheel could take 25–90 minutes and is exceptionally difficult to do successfully unless the damage is minor. Precision spoke-tension balancing (optional on high-performance wheels) can add 15–30 minutes.

WHEEL-REPAIR TOOLS (table 17-1)

Tool	Fits and considerations
NIPPLE WRENCHES (inaccurately called "spoke wrenches")	
Campagnolo UT-HU070	Fits 5.5mm hex-head nipples in many Campagnolo wheels
Generic multi-wrenches	Fit multiple sizes but usually not all critical ones, awkward to hold
Park SW-0	Black wrench fits 2.0/1.8mm-gauge spokes with 3.2mm nipples
Park SW-1	Green wrench fits 2.0/1.8mm-gauge spokes with 3.3mm nipples
Park SW-2	Red wrench fits 2.0/1.8mm-gauge spokes with 3.5mm nipples
Park SW-3	Blue wrench fits 12-gauge spoke nipples
Park SW-4	Yellow wrench fits 11-gauge spoke nipples
Park SW-7	Three-size multi-wrench that is painful to hold
Park SW-10	Adjustable clamping wrench fits all odd sizes and partially damaged nipples
Rika Spokey (red)	Comfortable, resists slippage, fits 3.3mm nipples
Rika Spokey (yellow)	Comfortable, resists slippage, fits 3.5mm nipples
Spline Drive S/T	Fits spline-drive nipples
VAR 51/1	Fits 2.0/1.8mm-gauge spokes with 3.3mm nipples
VAR 51/2	Fits 2.0/1.8mm-gauge spokes with 3.5mm nipples
SPOKE-SIZING TOOLS	
Hozan C700	Relatively inexpensive spoke-threading machine but impractical for more than 2–3 spokes at a time; valuable for creating replacement spokes in unusual sizes; ideal for wheels that just need a few spokes replaced
Phil Wood Spoke Threading Machine	Cuts and threads spokes, difficult to cost-justify, difficult to create consistent length of threading (makes truing more difficult)
DT Spoke Ruler	Inexpensive spoke ruler measures in millimeters and inches but aluminum gauge notches lose accuracy quickly
Phil Wood Spoke Length Gauge	Expensive, precise, durable, and measures millimeters and inches; superior variety of gauge notches that retain accuracy
Wheelsmith TR-001	Precise, durable, and measures millimeters and inches; limited variety of gauge notches
TENSION METERS (all choices need periodic recalibration, check with supplier for price and availability)	
Hozan C737	Expensive, fragile, precise readings, poor documentation and accuracy
Wheelsmith N001	Less expensive, durable, less-precise readings, good documentation
DT Digital Tension Meter	Very expensive, fragile, precise digital readings, good documentation
DT Dial Tension Meter	Expensive, fragile, precise dial-gauge readings, good documentation
Park TM-1	Least expensive, durable, less-precise readings, very easy to learn to use, good documentation, includes tool for measuring spoke gauge
SPOKE CUTTERS	
Small bolt cutter (various)	Heavy-duty spoke cutter for cutting out old spokes
Eldi 297	Cuts excess spoke off at nipple head but fits inside few rims
Hozan C216	Cuts excess spoke off at nipple head but fits inside few rims
DISHING TOOLS	
Campagnolo N	Slow to use, fits 26" and larger only
Park WAG-4	Light-duty tool fits 20" wheels and larger, only tool that works with tire in place; best use is for determining wheel dish error before tire removal
Park WAG-3	Light-duty folding tool, fits 26" wheels and larger
VAR 143	Heavy-duty, quick and easy to use, fits 20" wheels and larger

Continued

COMPLICATIONS
Hub adjustment is loose
A wheel cannot be trued if the hub adjustment has any free play. The mechanic changes the existing adjustment by eliminating free play. The mechanic is responsible for returning the adjustment to at least as good as it was originally. The mechanic is not responsible for making the adjustment more correct than it started out, unless the customer agrees to pay for a hub adjustment.

Rounded wrench-flats on nipples
As soon as one rounded nipple is encountered, turn all the nipples on the wheel to see if others will be a problem. A wheel with many damaged nipples is not cost effective to repair. A damaged nipple can be turned or removed with a Park SW-10 nipple wrench.

Frozen nipples
As soon as one frozen nipple is encountered, turn all the nipples on the wheel to see if others will be a problem. A wheel with many frozen nipples is not cost effective to repair. A frozen nipple can be turned or removed with a Park SW-10 nipple wrench, although it is often necessary to find a way to keep the spoke from turning.

Broken spoke
A broken spoke is routine in itself and not necessarily a complication. On a rear wheel, it often leads to freewheel removal, which itself can become very problematic.

WHEEL-REPAIR TOOLS (table 17-1 continued)

Tool	Fits and considerations
SPOKE-STABLIZING TOOLS	
Twist Resist 2	Securely and harmlessly grips spokes to prevent twisting and wind-up, left-hand and right-hand versions available, invaluable with straight-pull and non-round spokes
Slot-type tools (various)	Made by various manufacturers, not as effective as Twist Resist 2
AXLE ADAPTERS	
Cannondale QCTL108	Enables installation of Cannondale Lefty wheel in regular truing stand
Cannondale HD122	Enables installation of any 20mm-axle wheels in regular truing stand
RIM REPAIR TOOLS	
Bicycle Research RS-1	Pliers-type tool squeezes blips out of rims and aligns offset spliced rim seams
TRUING STANDS AND STAND ACCESSORIES	
United Bicycle Tool CV-290	Metric feeler-gauge set for measuring round, lateral, and dish errors
Hozan A340	Oversize motorcycle-wheel true stand
Pure Cycle True Stand	High-quality consumer model, adequate for shop use, eliminates need to adjust play out of hub
Park TS-2	Durable, easy wheel in/out, easy adjust of reading gauges
Park TS-7	Consumer-model stand that will cost more time than its low price justifies
Park TSB-2	Tilt base for Park TS-2 helps compensate for mounting TS-2 at poor height
Park TS-3	Expensive, best stand for use with dial gauges, potentially most accurate built-in dish adjustment, eliminates need to adjust play out of hub
United Bicycle UB-DI	Dial indicator for adding to existing true stand that can provide readouts to .025mm; unnecessary accuracy, not a time saver
VAR 74	Awkward wheel installation and indicator adjustment
SUPPLIES	
DT Spoke Freeze	Thread-preparation compound reduces corrosion and vibration loosening, is applied to assembled wheel
Wheelsmith Spoke Prep	Thread-preparation compound reduces corrosion and vibration loosening, can only be applied during assembly
Sanford Sharpie Fine Point permanent marker	Used for marking on rim to keep track of correction zones and tension readings

Multiple broken spokes

Multiple broken spokes can be encountered several different ways: The wheel may come into the shop with several broken spokes; several spokes may break while truing the wheel; or there may be only one broken spoke currently but evidence of other previously broken spokes due to the presence of mismatched nipples or spokes. The problem is that a wheel with multiple broken spokes is certain to break more spokes soon. Replacing the current broken ones becomes a very temporary repair that costs the customer a lot of money in the long run, especially if it is done over and over again.

Damaged spokes

Spokes may be bowed, bent, kinked, or chewed up. Most bows and bends are not a problem, but a kinked spoke (sharp bend) is weak.

The most common damage is for all the head-in spokes in the right flange to be chewed up by a chain that has shifted past the innermost rear cog. Although these spokes are weakened, one must balance the fact that they could have some reasonable life left against the fact that the only cost-effective repair for the shop is to rebuild the wheel (complicated by the issue of whether or not to rebuild with the same rim). It's usually best to true a wheel with chewed-up spokes and rebuild it completely if and when the spokes begin to break.

Replacing spokes of unusual length

It is very likely that customers will bring in wheels for which the shop has no matching lengths of spokes. Hozan makes an inexpensive spoke threader that is a better choice than turning away the work or ordering the spokes.

Spokes protruding past nipples

When spokes protrude past the nipples, they may puncture the tube, or the nipples may run out of thread.

A small amount of protrusion in a rim that has nipples down in a recessed well is not a problem. If the end of the spoke can reach the rim strip, then it must be ground down with a small stone on a rotary tool or filed if accessible. This is time consuming.

If the spoke protrudes, the nipple is hard to turn, and the spoke tension is low, the nipples are running out of thread on the spoke. Since proper tension cannot be achieved, the wheel is unreliable.

Bent rims

Four types of bent rims may be encountered. These are radial flat spots, simple lateral bends, bent rim beads, and collapsed rims.

Radial flat spots are revealed by having loose spokes in the very section of the wheel that should be loosened in order to make the rim more round. These radial flat spots are caused by impact to the rim that occurs in-line with the plane of the wheel (such as hitting curbs or landing too hard). Repair is possible, but success is rare.

Simple lateral bends are revealed by having loose spokes just in the section of the wheel on the side that should be loosened to correct a lateral error or by very tight spokes right where it would be best to tighten some to correct a lateral error. These lateral bends are caused by impact to the rim from the side. Repair is possible, but success is rare.

Another type of rim bend is a ding in the bead. The outer perimeter of the rim is deformed, but the body of the rim is unharmed. If the bead is collapsed straight in, there is no real problem and no solution. If the bead is deformed outward, it can be pressed back in with some success.

Rims can collapse catastrophically. The wheel will have a shape like a potato chip, with two large wobbles to the right alternating with two large wobbles to the left. This is unrepairable.

Cracked rims

Cracks can occur in rims at the nipple holes, at the inner perimeter of the sidewall, or in the sidewall. In all these cases, the rim is useless. Cracks around nipple holes or at the inner perimeter of the sidewall usually indicate excessive spoke tension. Cracks in the face of the sidewall may be from abuse or, more likely, from excessive rim wear.

Worn-out rim sidewalls

Worn-out sidewalls occur primarily on off-road bikes that are used in a lot of wet conditions. The dirt being ground between the brake pads and the rim wears away the rim surface. Although texture is a good indicator of wear, the best indicator is a concave shape (curved in) to the sidewall. Most rims have flat surfaces or convex surfaces. Rim failure is imminent and can be catastrophic.

Poor-quality rim seams

Rim seams can be offset, narrow, fat, or flat at the bead. A Bicycle Research RS1 can be used to eliminate offset on non-welded rims or to squeeze down a fat seam. If a rim has a narrow seam or a very short radial dip at the seam, the error at the seam should be ignored while truing the wheel. Any error at the seam that includes less than the distance between the two spokes adjacent to the seam is a seam problem, not a true problem.

Poor-quality rims

Inexpensive bikes often have rims that are so poorly made that both beads cannot be round at the same time and/or both sidewalls cannot be true at the same time. If one side looks round and true and the other jumps all over the place, then rim quality is to blame and further truing is a waste of time.

Tubular tire on rim to be trued

Tubular tires (glued on) present problems with correcting round, dish, and replacing a nipple. The shop cannot afford the expense of removing and re-gluing within the normal price of truing a wheel. In addition, many shops refuse to glue tubulars because of liability.

If the rim is box shaped, then radial truing can be done by setting the truing stand radial-true indicators to the inner perimeter of the rim. If the rim has an aerodynamic profile, then nothing is possible except eyeballing the round.

Dish is problematic on tubular rims because the tire interferes with the dish tool, and it is not unusual for the tire to wobble back and forth on the rim. The best solution is to deflate the tire and deflect it enough so that the dish tool can rest on the rim.

Nipple replacement is a problem because the tire must be partially unglued from the rim. Usually lifting up a 2-inch segment is adequate. Using an unattached spoke, feed the spoke up through the nipple hole at angle so that it comes out beside the tire, attach the nipple, then use the spoke to pull the nipple down into the rim. Remove the spoke from the nipple, then thread the nipple onto the spoke that is coming from the hub. *Be sure to put fresh glue under the section of the tire that was lifted!*

Mis-laced wheels

Usually mis-laced wheels are encountered when truing up a wheel that has just been laced. There may either be erratic tight and loose spokes or there will be a pattern of tight and loose spokes.

Erratic tight and loose spokes usually indicate that a few spokes were installed wrong, such as one two-cross and one four-cross in a wheel that is otherwise fully three-cross. Find and fix the offending mis-laced spokes.

A pattern of tightness and looseness will usually have alternating pairs, with two in a row tight, then two in a row loose. Each pair would include one pulling spoke and one pushing spoke. When this pattern occurs, it indicates that one whole side is mis-laced (all the spokes at least one hole off from where they should be in the flange). The wheel should be re-laced.

ABOUT THE REST OF THIS CHAPTER

The next section is about truing a wheel that has no rim damage, broken spokes, or damaged nipples. Everything in this section is also part of the process of repairing a wheel with rim damage, broken spokes, or damaged nipples. After the section on repairing the undamaged wheel is a section on replacing damaged nipples and broken spokes. The

procedure for this section goes only as far as necessary to recover from the damage, then refers back to truing an undamaged wheel to complete the job. The last section is concerned with repairing damaged rims, which once again only goes as far as recovering from the damage, then refers back to the first part on truing undamaged wheels.

TRUING WHEELS WITH UNDAMAGED RIMS, SPOKES, AND NIPPLES

AVOIDING COMMON PITFALLS

Based on decades of teaching experience, there are ten common pitfalls to truing wheels a mechanic should watch out for at all times. The pitfalls are listed here and in some cases are repeated as the procedure is described later on.

Pitfall #1: Avoid turning the nipple the wrong way. Nipples are a right-hand thread, just like any type of jar lid. The problem is that while turning the nipple, the viewpoint is the same as looking at the "jar" upside down. With the tire off and looking at the nipple from the tire-side of the rim (the nipple's "tire end"), the viewpoint is the same as looking at the top of the "jar lid." When the view is of the end of the nipple that the spoke attaches to (the "hub end"), it is the same as looking at the "jar" upside down.

Try this experiment. Get any empty jar (preferably clear) and hold it upside down. Now, look through the bottom of the jar and turn the lid off. The lid had to be turned clockwise (the normal way to tighten lids) to get it off. Loosening a nipple when looking at it from "hub end" is just like loosening the lid on the upside-down jar. Tightening it is just the opposite. If you have trouble with this visualization technique, use a felt tip pen to draw a half-circle arrow on the inner perimeter of the rim around every fourth nipple in the *counterclockwise* direction. Turn nipples the direction the arrow indicates when tightening and opposite the arrow when loosening.

Pitfall #2: There is feedback designed into the wheel-truing procedure recommended in this chapter that confirms things are on the right track; don't bypass the procedure and lose the feedback. When correcting lateral (side-to-side) errors and radial (round) errors, set the truing stand so that its indicators *just barely contact the rim*. Then, a very small correction is made. If the correct adjustment is made there will be immediate feedback in the form of *the slight contact disappearing!* If it does not disappear, either the wrong spoke is being turned or the correct spoke is being turned in the wrong direction.

If the contact between the truing-stand indicator and the rim is too heavy, there will be no immediate feedback as to whether the correction is the right one. Then it is easy to do the wrong thing for a long time before discovering it or too much of the right thing, which is ultimately the wrong thing as well.

Along with this, keep the following guidelines in mind: Turning a nipple a whole turn is a huge adjustment; turning a nipple a half turn is a normal adjustment; and turning a nipple a quarter turn is a fine adjustment.

Pitfall #3: Don't make dish (rim centering to the hub) corrections backward, worsening instead of improving an out-of-dish problem. For some reason, many people have an intuitive understanding of how to correct a dish problem that is just the opposite of the correct way. When making dish corrections, *follow procedures, not instinct!*

Pitfall #4: Don't assume that once dish is checked and found to be correct, it will remain correct from then on. On rear wheels, there is a tendency for the rim to pull to the left slightly as the spokes get tighter. Advanced wheel mechanics use this to their advantage by tolerating minor errors to the right when the wheel is at low tension, expecting them to self-correct as the wheel is tightened. Another way that dish is sometimes lost is when starting with a well-dished wheel with a major round error. In correcting the round error, some substantial lateral error is created. In correcting the lateral error, the dish adjustment is lost. As a beginner, just keep checking wheel dish, even if it checked out fine early on.

Pitfall #5: Don't check for dish error when the wheel has significant lateral errors. This is like using a level to check whether a warped stud is perpendicular to the ground. Where the level is put completely changes the interpretation of any error. Always be sure that the lateral true is acceptable before using a dish gauge.

Pitfall #6: Don't lose track of the right and left sides of the wheel when making dish corrections. A good technique is to always wrap a rubber band around the right end of the axle before starting to true the wheel. Always install the wheel in the truing stand with the rubber band on the right, and always start each dish measurement on the right side of the wheel. By using these habits consistently, the chance of getting turned around and performing a reverse correction is minimized.

Pitfall #7: Avoid assuming that the lateral alignment of the rim remains constant when correcting a series of radial errors. It is natural to lose some lateral true while adjusting radial. For this reason, after every three radial corrections, interrupt the process and go back and recheck for lateral errors. What makes switching back and forth between radial and lateral corrections so important is that a rim never moves strictly side to side. Think of the rim as a swinging pendulum. As it goes left of center, it goes up. As it goes right of center, it goes up. While working on radial errors, the wheel will develop more and more lateral error. If you work on radial errors for too long without backtracking to lateral-error correction, there will be more and more *false* radial errors. It's a vicious cycle.

Pitfall #8: Don't fail to balance the left- and right-side corrections when correcting a round error (I am getting a little ahead here, but just try to grasp this concept). If trying to move a section of the rim closer to the hub, spokes need to tightened. If only a left-side spoke is tightened, the rim will be pulled closer to the hub, but it will also be pulled closer to the left side of the hub, since that is where the spoke comes from. If a nearby right-side spoke is tightened an equal amount, it too will pull the section of rim closer to the hub but to the right side as well. Since both spokes were tightened equally and one pulled the rim left and the other pulled the rim right, the net effect is that the rim moved closer to the hub but stayed laterally stable (did not move closer to the left or right). For this reason, never use one spoke when correcting a radial error. If using two spokes, the amount each spoke should be adjusted will always be equal. If adjusting three spokes in a row (it gets trickier now), the total adjustment on left-side spokes has to equal the total adjustment on right-side spokes. For example, if the group of three included two left-side spokes straddling one right-side spoke, tighten the left-side spokes a quarter turn each (two quarters equals one half) and the one right-side spoke a half turn.

Pitfall #9: Don't make errors reading the spoke-tension-meter tool and don't make errors using math to average a series of readings. The tension meter does not read in familiar units like a ruler. If measuring something familiar, like a letter-size sheet of paper, with a ruler and the measurement was something ridiculous like 12" × 18", it would obviously need to be redone. Without any fundamental understanding of the realities of spoke tension and the units that tension is measured in, extreme care is called for. Watch out for these pitfalls:

Confusing very low readings with very high readings. The nature of the Wheelsmith tension meter is to simultaneously read "0" and "100" when measuring tension on a tensionless spoke. As readings of "100" are virtually impossible and readings of "0" are quite common, it is safe to assume the lower number. Pluck the spoke in question and trust what it feels like. If it sings like a bird, the "100" is right. If it has no tone at all, go with the "0."

Do not measure left-side spokes when determining a rear wheel's overall tension average. By nature, rear-wheel left-side spokes are significantly lower in tension than right-side spokes. It is the right-side spokes that reach maximum tension first, and if

left-side spokes are measured it will result in over-tightening the right side.

Part of tensioning the wheel is taking readings on a number of spokes and then averaging the readings. Over and over again, students at Barnett Bicycle Institute take ten readings ranging from 60 to 70 each, average them, come up with an answer of 72.3, then go on as though nothing were wrong. Their mistake is to have left out one of the readings in a group of ten but still divide by ten to get the average. Sometimes they make the opposite error of adding a number in twice. In this case the average will be near or below the lowest readings they took. *Be suspicious if an average is close to or beyond the lowest or highest numbers being averaged!*

Pitfall #10: Don't lose perspective; avoid seeing little errors as big errors. As the wheel takes longer and longer to complete, it is easy to become more and more able to see errors. A significant number of students at Barnett Bicycle Institute make substantial progress on a wheel *and become convinced that it was worse than when they started!* For this reason, it is imperative to measure errors before fixing them and measure them to determine when to stop, rather than relying on subjective judgment.

PREPARATIONS AND INSPECTIONS

1. [ ] Remove wheel from bike and skewer (if any) from hub.
2. [ ] Remove tire from rim.
3. [ ] Mark right end of axle with tape or rubber band.
4. [ ] Jerk axle side to side to check hub for play. (Adjust hub to eliminate play if hub is loose.)
5. [ ] Install wheel securely in stand with right side of wheel on right side of stand.
6. [ ] Put a drop of oil where each nipple enters rim and a drop of oil on the end of each nipple where spoke comes out.
7. Measure spoke at its midpoint to determine gauge. Check off closest of following measurements.
    ROUND SPOKE SIZES
    [ ]2.0mm   [ ]1.8mm   [ ]1.7mm   [ ]1.6mm
    [ ]1.55mm   [ ]1.5mm   [ ]Other: _____mm
    NON-ROUND SPOKE SIZES (measure the major and minor thickness)
    Minor thickness: _____mm
    Major thickness: _____mm

DT TENSION METER

The DT tension meter is made in two versions. One has a digital readout and the other has a dial gauge. Both take readings in millimeters. The table that comes with the tool converts the readings to units of Newtons. The procedures in this section use units of <u>k</u>ilograms of <u>f</u>orce (kgf). To convert kgf to Newtons, divide by .102, and to convert Newtons to kgf, multiply by .102. Reasonable accuracy (98%) and simplicity can be achieved by simply moving the decimal point one position. For example, 100 kgf becomes 1000 Newtons or 1000 Newtons becomes 100kgf.

With either tool, be sure it reads zero before starting. When using the dial-gauge tool, be sure to add the small-dial value (whole millimeters) and the large-dial value (hundredth millimeters) together to get the reading.

PARK TM-1 TENSION METER

When taking a reading, it is easy to get a false high value by releasing the tool too quickly—always release it very slowly and gently. If readings are inconsistent with a slow release, oil the spring at both ends and at the point it coils around the bolt.

The Park TM-1 has a needle that points to a scale. The values on the scale are *reading units*. In other words, they don't correspond to a known dimensional unit. Every fifth line on the scale is labeled in increments of five. Each line represents one unit.
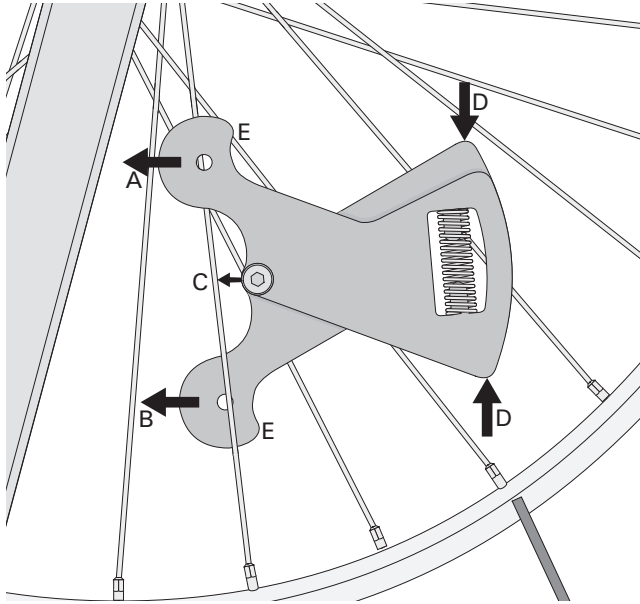
When initial readings are clearly low or high, it may be acceptable to simply choose the line that is closest to the indicator needle, but ultimately it is necessary to make finer distinctions. If the needle is exactly halfway between two lines, interpret the reading to a .50 increment. For example, if the needle points exactly halfway between the marked 20 line and the unmarked 21 line, consider the reading to be 20.50. If the needle is between two lines but closer to one than the other, interpret the reading to a .25 increment. For example, if the needle is between 20 and 21 but closer to 20, consider the reading to be 20.25; or if the reading is between the same two lines and is closer to 21, consider the reading to be 20.75.

The table that comes with the tool is used to convert the reading units to <u>k</u>ilograms of <u>f</u>orce (kgf), which are the units used in the following procedures.

WHEELSMITH TENSION METER

Before tension can be measured, get familiar with how to use the Wheelsmith Tensiometer. Take a look at figure 17.1 (page 17-9) to see how the tool is placed on the spoke. One ear of the tool goes over the spoke and
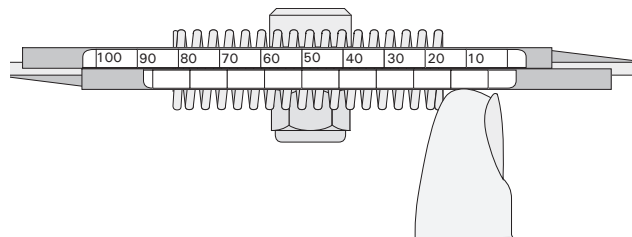
one goes under the same spoke. When the tool is installed correctly, it will hold itself on the spoke.

17.1 The Wheelsmith Tensiometer is placed on the spoke so that the ear marked "A" goes over the spoke and the ear marked "B" goes under the spoke. When point "C" contacts the spoke, squeeze the tool together at the points marked "D," so that the points marked "E" can catch on the opposite side of the spoke from point "C."

It is important where the tool is placed along the length of the spoke. The *entire* tool must be between the rim and the last point where the spokes cross each other on the way to the rim. Also, if the spokes are butted (thick on the ends and thin in the middle) the entire tool needs to be on the thin portion of the spoke. Sometimes butting is hard to see. Grasp the spoke between two fingertips and feel for a change as you slide your fingers from one end of the spoke to the other, or set a caliper tight on the spoke near the middle of its length and see if the caliper jams before it will slide all the way to the nipple.

One more important tip about the Wheelsmith Tensiometer is how to hold it while taking a reading. It is best to support it on one finger, as in the next picture. If held between two fingers, there is a chance the additional pressure will influence the reading.
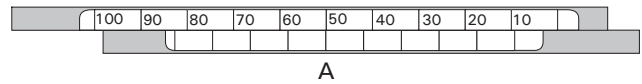

17.2 Holding a Wheelsmith Tensiometer while taking a reading. Note use of single finger—do not grasp!
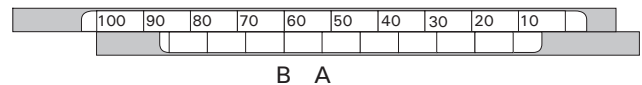
Reading increments of 10

Now look at the tool scale and figure out how to read it. The top scale has lines numbered 10 to 100 (right to left). The bottom scale has no numbers. The easiest reading to make is if one of the lines on the bottom scale touches one of the lines on the top scale. The reading is then the number adjacent to the line on the top scale that is being touched by a line on the bottom scale. (See following figures 17.3 and 17.4.)

A reading of 50

17.3 In this example, the reading on the Wheelsmith Tensiometer is 50 because the lower-scale line indicated by "A" lines up exactly with the upper-scale line marked "50."
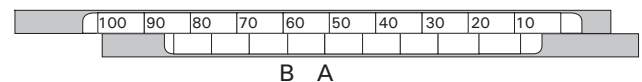
A reading of 60

17.4 In this example, the reading on the Wheelsmith Tensiometer is 60 because the lower-scale line indicated by "B" lines up exactly with the upper-scale line marked "60."

Reading increments of 5

If none of the lines on the bottom scale touch any of the lines on the top scale, look for the two lines that come closer to touching than any of the others. Let's say there is a line on the bottom scale that comes close to touching the 50 line on the top scale, and there is another line on the bottom scale that comes equally close to touching the 60 line. In this case, split the difference between 50 and 60 and call the reading a 55. (See following figure 17.5.)

A reading of 55

17.5 In this example, the lower-scale line indicated by "A" is close to the upper-scale line marked "50," the lower scale line indicated by "B" is close to the upper-scale line marked "60," and they are equally close. Consequently, the reading is halfway between 50 and 60, which is 55.
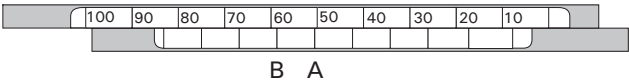
Reading increments of 2.5 and 7.5

When no lines touch, it will not always be the case that the two closest will be equally close to the lines they don't quite touch. Sticking with the above example, if the line close to 50 is closer to 50 than the line close to 60 is close to 60, then the reading would be 52.5. If the reverse were true, with the line near 60 being the closer one, then
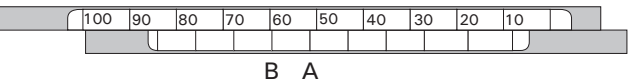
the reading would be 57.5 instead. (See following figures 17.6 and 17.7.)

A reading of 52.5

17.6 In this example, the reading on the Wheelsmith Tensiometer is close to 50 because the lower-scale line marked "A" is closer than any other line on the lower scale line is close to any other line on the upper scale. The reading is more than 50 because the "A" line is on the 60 side of 50. The reading is below 55 because the "A" line is closer to 50 than the "B" line is close to 60, so the reading is 52.5.

A reading of 57.5

17.7 In this example, the reading on the Wheelsmith Tensiometer is close to 60 because the lower-scale line marked "B" is closer than any other line on the lower scale is close to any other line on the upper scale. The reading is less than 60 because the "B" line is on the 50 side of 60. The reading is above 55 because the "B" line is closer to 60 than the "A" line is close to 50, so the reading is 57.5.

USING CONVERSION TABLES

All brands of tension meters come with conversion tables that show what the force on the spoke is for the reading value on the tool. The tables have different columns for different spoke types. Find the correct column and the row with the reading value seen on the tool, then move horizontally to the force column (kgf or Newton) to determine the force.

Interpolation

The increment of increase of force from one row to the next is usually quite large. A greater degree of precision is necessary. It would be simple if the tables had more rows and more precise increments, but since they do not, a mathematical process called interpolation is needed to interpret the in-between values.

The following examples are for a Wheelsmith Tensiometer and its accompanying table. The process is equivalent when using the tables that come with other brands of tools.

Assume a batch of readings have been taken, and they averaged 62.5. The spoke gauge is 1.8mm. On the accompanying chart (figure 17.8), the average reading is found in the reading column (halfway between 60 and 65), and the kgf is interpolated to be 118 (halfway between 108, which is the tension for a reading of 60, and 128, which is the tension for a reading of 65). This interpolation is very simple

because the average reading is exactly halfway between two readings on the table.

Spoke Tension in Kilograms of Force (kgf)

Tensiometer Reading	SS-14 2.0	SS-15 1.8	DB-14 1.7
10			
15			
20			48
25		49	52
30		53	57
35		58	63
40		64	70
45	51	71	78
50	55	80	90
55	61	92	105
60	68	108	126
65	77	128	158
70	89		
75	104		
80	127		

62.5 = 118

17.8 A Wheelsmith Tensiometer chart.

Average readings are not always found on the table or halfway between two numbers on the table. The mathematics for interpolating the values at any point between two numbers on the table is a process of finding a correspondence of values in one column to the values in another column.

For example, if the increment of change in the kgf column from one row to the next is 5 (60 to 65), but the increment of change in the reading column for 2.0mm spokes for the same two rows is 10 (72 to 82), then there is a 1:2 correspondence between the values in the two columns (see following example table). In other words, each increase of 1 in the reading column corresponds to an increase of 2 in the kgf column. Therefore, a reading of 61 (increase of 1) is a kgf of 74 (increase of 2) and a reading of 62 (another increase of 1) is a kgf of 76 (another increase of 2).

Tool reading	2.0mm spoke (kgf)	1.8mm spoke (kgf)
60	72	87
65	82	100

This counting-off approach works fine if the average reading value is always a whole number and the cor-

responding increases in the kgf columns are always all in whole numbers, but when any of the increments are not whole numbers, a better method is needed. This method requires three mathematical steps: a division step, a multiplication step, and an addition step. In the next example, the exact same interpolation as the previous example is done utilizing the three mathematical steps. This method is demonstrated by the two following examples.

Example 1: The average reading of the tool is 61, which falls between 60 and 65 in the example table below. These two reading values are called the *lesser reading* and the *greater reading* in the example. The difference between the *average reading* and the *lesser reading* is called the *reading increase* in the example. The difference between the *lesser reading* and the *greater reading* is called the *reading range.* The *reading range* from 60 to 65 is 5. The readings 60 and 65 correspond to the kgf values 72 and 82 in the 2.0mm spoke column below. These two kgf values are called the *lesser kgf* and the *greater kgf* in the example. The difference between the *lesser kgf* and the *greater kgf* is the *kgf range.* The *kgf range* from 72 to 82 is 10.

Step 1: Divide *reading increase* by *reading range*:
   $(1 ÷ 5 = .2)$.
Step 2: Multiply *kgf range* by result of step 1:
   $(10 × .2 = 2)$.
Step 3: Add result of step 2 to *lesser kgf* value:
   $(72 + 2 = 74)$.

Tool reading	2.0mm spoke (kgf)	1.8mm spoke (kgf)
60	72	87
65	82	100

Example 2: The average reading of the tool is 62.2, which falls between 60 and 65 in the example table (above). These two reading values are called the *lesser reading* and the *greater reading* in the example. The difference between the *average reading* and the *lesser reading* is called the *reading increase* in the example. The difference between the *lesser reading* and the *greater reading* is called the *reading range.* The *reading range* from 60 to 65 is 5. The readings 60 and 65 correspond to the kgf values 72 and 82 in the 2.0mm spoke column above. These two kgf values are called the *lesser kgf* and the *greater kgf* in the example. The difference between the *lesser kgf* and the *greater kgf* is the *kgf range.* The *kgf range* from 72 to 82 is 10.

Step 1: Divide *reading increase* by *reading range*:
   $(2.2 ÷ 5 = .44)$.
Step 2: Multiply *kgf range* by result of step 1:
   $(10 × .44 = 4.4)$.
Step 3: Add result of step 2 to *lesser kgf* value:
   $(72 + 4.4 = 76.4)$.

Fill in the blanks in the following calculator procedure, then enter the values and function keys in the sequence indicated to interpolate the kgf value from the tool reading.

Average reading		Lesser reading		Reading increase
_____	−	_____	=	_____
Greater reading		Lesser reading		Reading range
_____	−	_____	=	_____
Reading increase		Reading range		Step 1 result
_____	÷	_____	=	_____
Greater kgf		Lesser kgf		Kgf range
_____	−	_____	=	_____
Kgf range		Step 1 result		Step 2 result
_____	×	_____	=	_____
Step 2 result		Lesser kgf		**KGF VALUE**
_____	+	_____	=	_____

ESTABLISHING STARTING TENSION

In the next step, measure the tension on the spokes (right side only if a rear wheel, left side only if a front disc wheel). The reason to start with this measurement is that the process of truing more than likely will add tension to the wheel. If the wheel starts out with a high tension, it might end up being tightened too much. Usually, if the tension is over 80kgf, it makes sense to loosen the wheel before starting to true the wheel. Resist the tendency to tighten a wheel that starts out loose (under 80kgf); a loose wheel automatically becomes tighter from the truing process (tightening the wheel before truing will lead to too much tension). If the wheel does not gain enough tension from truing, more tension can be easily added at the end of the truing process.

8. [ ] Measure tension on ten consecutive right-side spokes (left on front disc), record readings in following blanks, and total.

   _____ + _____ + _____ + _____ + _____

   _____ + _____ + _____ + _____ + _____ = _____

9. [ ] Divide step 8 total by 10   ÷ 10
   Average reading is: = _____

10. [ ] Convert average reading to approximate kgf for spoke gauge in use: _____ (use lowest listed value if kgf column is blank adjacent to current average reading).
11. [ ] *Choose:* Tension is <70kgf or >70kgf (circle one choice).

NOTE: If <70kgf *circled in previous step, skip to step 13):*

12. [ ] *If >70kgf is checked in step 11:* Loosen all spokes one half turn and repeat steps 8–12 until average is <70kgf.
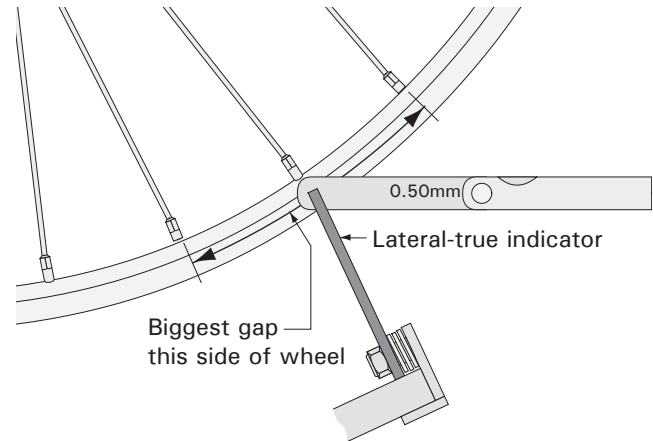
CORRECTING LATERAL ERRORS

Lateral error needs to be corrected before radial error or dish error because measuring and correcting radial or dish errors is compromised if there is significant lateral error. The basic technique when correcting lateral error is to set the truing indicators to barely rub the rim at one point as the wheel rotates in the stand, stop the wheel at that point, and tighten one spoke just enough to eliminate the rub. Then the indicators are moved in just enough to create another rub, which is then eliminated. This is repeated over and over again until the lateral error becomes insignificant (<.5mm). Because there is no way to predict how many times it will be necessary to repeat the process, the next steps are written as a repetitive cycle, each time ending with: "**Insert .5mm feeler gauge in gap to determine if it is<.5mm and return to step 16 if it is not.**" Once the tolerance is met, move on to the next step.

Depending on the brand of truing stand being used, there are different techniques to setting the truing indicator(s) so that they just rub. If using a stand such as the VAR 74, which has separately adjustable left and right indicators, it takes a little adjustment to set them into position. First, just get the wheel spinning at a good clip. As it spins, try to get an idea of where the rim is the majority of the time. If it is running generally straight but with a few pronounced wobbles, decide whether those wobbles are primarily to the right or to the left. If they are predominantly to one side, use the indicator on that side of the stand. If unsure, or the rim appears to wobble equally to the right and the left, alternate each lateral correction between the worst rub on the left and the worst rub on the right. If using the Park stand, the two indicators move in simultaneously to the rim. This can be a blessing or a problem. It's a blessing because the indicators determine by themselves whether the worst rub is to the right or left side. It's a problem when the wheel or stand is off-center and it keeps rubbing on one side when the worst wobble is to the other side. This can be solved by either turning the wheel around in the stand or

finding something to wedge underneath one of the indicators so that it does not move in anymore.

Start the next series of steps with a measurement to determine whether there is a need to make corrections. Use feeler gauges to measure the error. Start the wheel spinning and adjust the lateral-true indicator(s) until there is the slightest detectable rub. Now turn the wheel slowly and find what looks like the largest gap that occurs between the lateral-true indicator that rubbed the rim and the rim.

17.9 Using a .5mm feeler gauge to check whether lateral error is within acceptable tolerance.

13. [ ] Spin wheel and set lateral-true indicators so that they just barely touch rim.
14. [ ] Turn wheel slowly and find largest gap between rim and indicator that touched rim.
15. [ ] Insert .5mm feeler gauge into gap to determine if gap is:
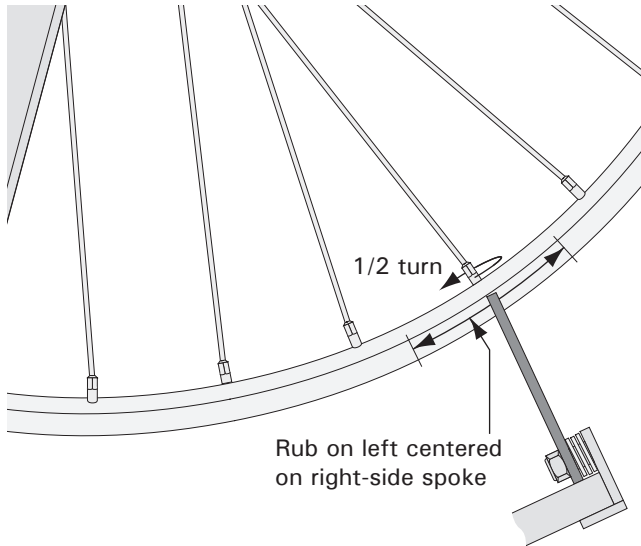   ≥*.5mm* (bad) <*.5mm* (good)

A handy technique for the beginner is to use a "marker" on the rim at each point a correction will be made. The marker could be a 1/2" piece of tape, such as masking tape. Each time a rub is found, mark the center by putting the tape on top of the rim (not on the face where the truing indicator might knock it off). Alternatively, use two markers to mark where a rub begins and where it ends.

16. [ ] Spin wheel slowly and stop it at the point where rim just rubs the lateral-true indicator. If wheel rotates past rub, be sure to turn wheel back so rim is contacting indicator. Find center of rub zone, not just one end.
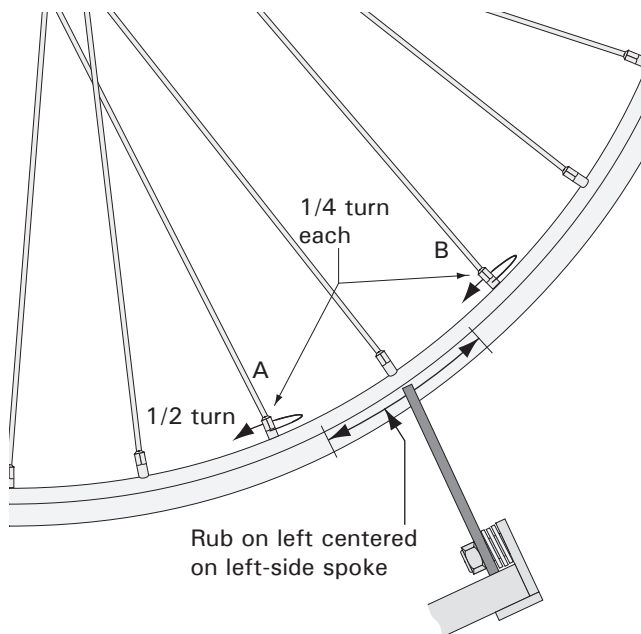
In the next step, pick which spoke(s) to use to correct the rub. It will always come from the opposite side of the wheel than where the indicator is rubbing. If the indicator is rubbing on the right side of the rim over a short distance directly opposite a left-side spoke, then tighten that left-side spoke one half turn. If the rub on the right is short and halfway between two left-side spokes or slightly longer and includes two left-side spokes, then it is necessary to pick which spoke to use for the correction. Pluck the two spokes in question. If one is obviously looser than the other, tighten

it. If they are equal, then it is OK to split the half turn correction between them with a quarter turn each. Beginners should stick with using one spoke.

17. [ ] Find spoke (or two, at most) from side of hub opposite side of rub that is closest to center of rub (or lesser-tensioned spoke of pair that are both close to center of rub) and tighten it one half turn (quarter turn each if adjusting two spokes).

1/2 turn

Rub on left centered
on right-side spoke

17.10 If there is a short rub on the left centered exactly opposite a right-side spoke, tighten that spoke one-half turn.

1/4 turn each

B

A

1/2 turn

Rub on left centered
on left-side spoke

17.11 There is a short rub on the left that is centered between two right-side spokes; if A is looser than B, tighten A one half turn. If they seem equally tight, then tighten them both a quarter turn.

18. [ ] Move rub section past true indicator again to check that rub is eliminated.

19. [ ] Spin wheel and set lateral-true indicators so that they just barely touch rim.
20. [ ] Only if wheel looks reasonably true, turn wheel slowly and find largest gap between rim and indicator that touched rim. If errors remain obvious, return to step 16 now.
21. [ ] Insert a .5mm feeler gauge in gap to determine if it is <.5mm and return to step 16 if it is not.

NOTE: If gap is <.5mm go to step 22.

CORRECTING RADIAL ERRORS

Radial-error correction is probably the most demanding part of truing wheels. Many judgments have to be made about how many spokes to include in a correction. Both rubbing and the lack of rubbing may indicate errors. So, some corrections must be done by loosening and some by tightening. Radial corrections must constantly be interrupted to recheck and correct any lateral errors that develop while working on round. Remember: Make sure that the total turns of correction on one side of the wheel equal the total turns of correction on the other side of the wheel.

Radial errors can either be a place where the rim is further or closer to the hub than a perfectly round wheel. Those places where the rim is further from the wheel center are called "bumps," and those that are closer to the wheel center are "dips." Think of it as though the outer perimeter of the rim were a road, and the irregularities on the road are bumps and dips.

The strategy when correcting radial errors is to take care of bumps before taking care of dips. There are two reasons for this. First, it is easier to detect the bumps (by the rim rubbing on the truing indicators) than it is to detect the dips (by looking for gaps). Second, it is like building a nice, flat highway through hilly terrain. It is easier to smooth off the hilltops than it is to fill in the valleys. Also, by reducing the size of the hills, you also diminish the valleys—if you don't get that right away, you will. Rims are not quite the same but the effect is. By working on eliminating bumps first, there will be less to do with dips.

The first step is to measure the radial error, so it is known how much work must be done and when progress has been made. To do this, set the truing indicator so that it barely scrapes against the outer perimeter of the turning rim. Turn the rim slowly and find the biggest gap between the rim and the truing indicator, then use a feeler gauge(s) to measure this gap.

If the truing stand is a VAR or similar model, there is a separate plate that slides up and down that is the radial-true indicator. If the plate will tip a little to the side, it can
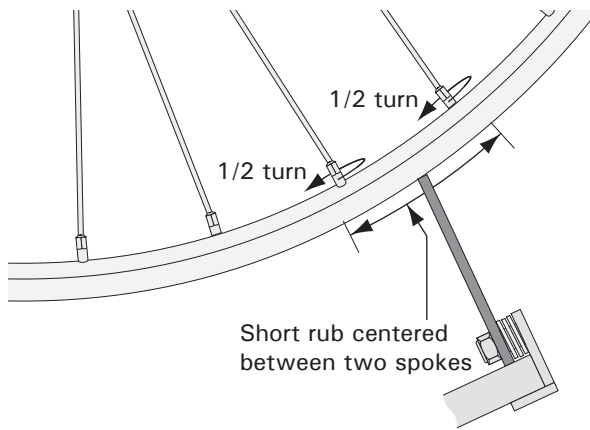
be set so that it contacts one edge of the rim only. This is preferable! The Park stand uses the same indicators for radial true as it does for lateral true. Tighten the knob under the big arm so that the indicators will miss the rim entirely when they are adjusted in toward the rim. When the indicators are under the rim, start the rim turning and loosen the knob under the big arm until an indicator just touches the rim. In almost every case, it will touch at one edge of the rim before the other. Once again, this is preferable. When correcting radial true, it is preferable to get information from only one edge of the rim. The adjustment for the radial at the right edge of the rim is the identical adjustment for the radial at the left edge of the rim. When correcting deviations observed at one edge, the other edge is getting rounder simultaneously. Since it is impossible for any rim to have exactly identical left and right edges, if the indicator touches both edges at once you will get confusing information. Adjust the radial by one edge of the rim and trust that the other will also end up in tolerance.
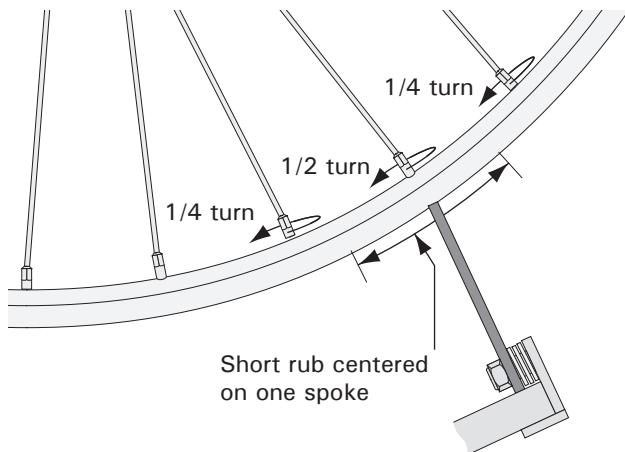
Eliminating bump errors

22. [ ] Spin wheel and adjust radial-true indicator so that rim just barely rubs it as rim turns. Observe whether rub is on left or right edge of rim.
23. [ ] Turn rim slowly and look for biggest gap between indicator and edge of rim *on same side as rub occurred.* Stop rim at biggest gap.
24. [ ] Insert .5mm feeler gauge into gap to determine if gap is:
    ≥.*5mm* (bad) <.*5mm* (good)

With the radial indicator still set in the same way, give the wheel another spin and again find the slight rub that is occurring. If the wheel spins past the rub, be sure to back up to it. Figure out where the rub begins and where it ends. Put a marker on the inner perimeter of the rim at the center of the rub. The rub might be short (including two or three spokes in its range) or long (including four or more spokes in its range). Long rubs in the early going often indicate that the truing indicator is set to tight against the rim. See if the indicator can be set looser to get a shorter rub.

A different technique is required for fixing a short rub including two spokes than a short rub including three spokes. For two spokes, tighten both spokes equally (generally a half turn each or perhaps just a quarter). For three spokes, tighten the two on the ends a quarter turn each and the one in the middle a half turn. With this method, the total number of turns on right-side spokes equals the total number of turns on left-side spokes; therefore, the impact on the lateral true will be minimized.
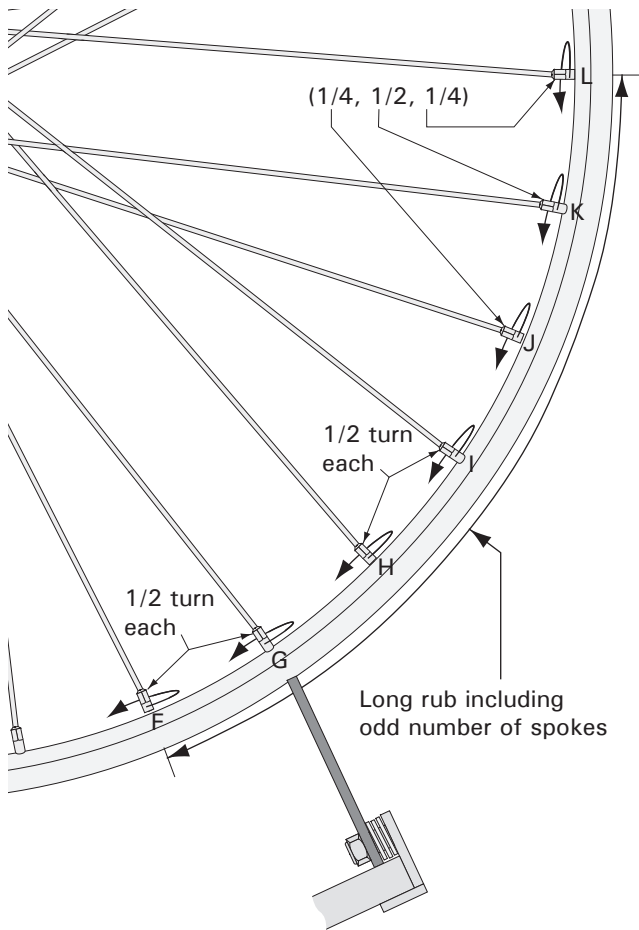

17.12 Fix a radial bump including two spokes in its range by tightening both spokes equally.

17.13 Fix a radial bump including three spokes in its range by tightening the end spokes a quarter turn each and the middle spoke a half turn.

Fixing rubs over four or more spokes is different. The easiest way to deal with a bigger problem is to make it a number of smaller problems. In this case, instead of putting the marker in the middle of the rub, put a marker at each end of the rub. Instead of thinking of the rub as one big error, think of it as a number of two-spoke rub errors. (If the rub range included an odd number of spokes, the last correction will be a three-spoke correction [1/4, 1/2, 1/4], instead of a two-spoke correction like all the others.) If you are unclear about this system, follow the two examples below. The first example is a rub that includes four spokes in its range. For the sake of this discussion, the spokes will be called spoke A, B, C, and D. Correct this four-spoke rub by treating it like two short rubs involving two spokes each. Tighten A and B a half turn each (first correction) and then C and D a half turn each (second correction). The second example involves a longer rub including seven spokes, called spokes F, G, H, I, J, K, and L. The first correction is to tighten F and G a half turn each. The second correction is to tighten H and I a half turn each. The third correction is to tighten J

a quarter turn, K a half turn, and L a quarter turn. Once again the rule of tightening left- and right-side spokes equal amounts applies.

(1/4, 1/2, 1/4)

L

K

J

1/2 turn each

I

H

1/2 turn each

G

F

Long rub including odd number of spokes

17.14 Fix a radial bump of four or more spokes by breaking it down into short sections including two spokes, with the last section including three spokes if the total range of the rub included an odd number of spokes.

As with the correction of lateral rubs, if these corrections are done properly, the result will be that the rub disappears. If it does not, either nipples are being turned the wrong way, the range of the rub has not been determined accurately, or the truing indicator has been set too tight so that the rub was not light.

Once the rub goes away, go on to the next correction. After three corrections (count every two- or three-spoke group as a correction), interrupt the radial work and check the lateral again, correcting it if necessary until the largest gap is <.5mm.

25. [ ] Rotate rim slowly to find radial rub and identify center of range of rub.
26. [ ] Tighten appropriate group of spokes (two or three) so that spokes on each side of the wheel are tightened equal amounts (1/2 + 1/2 or 1/4 + 1/2 + 1/4).
27. [ ] Move rim back and forth to check that rub is gone within original range of rub.

28. [ ] Spin wheel and adjust radial-true indicator to barely rub again.
29. [ ] Turn wheel slowly to check for largest gap at edge where rub occurs. Check if gap is <.5mm and repeat steps 25–29 if not. After every three cycles of steps 25 through 29, check and correct lateral errors until largest gap is <.5mm.
*NOTE: At end of step 29 if largest gap is <.5mm, proceed to **CORRECTING DISH ERRORS** (page 17-16).*
30. [ ] If largest gap is >.5mm but setting truing indicator to slight contact results in rub around rim at a number of sections including over 50% of spokes, proceed to *Eliminating dip errors* (immediately following this step).
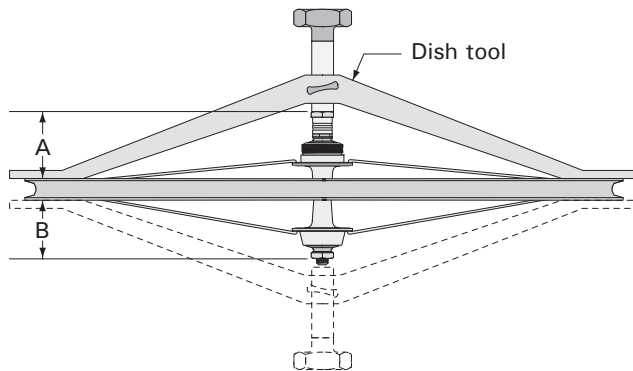
Eliminating dip errors

The very nature of a dip error makes it harder to find because the truing indicator skips over the dip without any obvious feedback that the error is there. Make this an advantage by setting the radial-true indicator so that it rubs so firmly against the rim that it rubs everywhere but one short range. This quiet range is the worst radial dip. Determine where the dip begins and ends and put a marker on the inner perimeter of the rim at the center of the quiet range. Just like the bumps, dips can involve two spokes, three spokes, or longer sections of four or more spokes that must be broken down into a series of two- or three-spoke corrections. Other than looking for the quiet range instead of a rub, the only difference between fixing dips instead of bumps is that spokes must be *loosened* in the quiet range instead of tightened in the rubbing range. A correction is completed when the rim just barely rubs at the marker where before it was quiet.

31. [ ] Set radial-true indicators firmly against outer perimeter of rim so that only one short section of rim does not rub as wheel is rotated.
32. [ ] Rotate rim slowly to find quiet range and place marker at center of quiet range.
33. [ ] Loosen appropriate group of spokes (two or three) so that spokes on each side of wheel are loosened equal amounts (1/2 + 1/2 or 1/4 + 1/2 + 1/4).
34. [ ] Move rim back and forth to check that rub has developed at marker.
35. [ ] Spin wheel and adjust radial-true indicator to barely rub again.
36. [ ] Turn wheel slowly to check for largest gap at edge where rub occurs. Check if gap is <.5mm and repeat steps 31–36 if not. After every three cycles of steps 31–36, check and correct lateral errors until largest gap is <.5mm.
37. [ ] If largest gap is <.5mm proceed to **CORRECTING DISH ERRORS** (immediately following).

CORRECTING DISH ERRORS

Dish corrections are made to center the rim in the bike. A rim can be moved to the right by tightening all the right-side spokes or loosening all the left-side spokes. A rim can be moved to the left in the opposite way.

17.15 Dish error exists when dimensions A and B are not equal. The dish tool is used to make this comparative measurement.

Dish and spoke tension

The average tension of the wheel has changed since lateral and radial errors were corrected. After determining a dish error exists, you need to know whether to tighten or loosen spoke tension and on which side. If tension is still low, spokes must be tightened. If the tension is too high, spokes must be loosened to correct dish. If the tension is fine, a mix of tightening and loosening spokes is needed to correct the dish error.

For example, if a dish error is detected that would be corrected by either tightening all the right-side spokes a half turn or loosening all the left-side spokes a half turn but the tension on the wheel is correct, then the dish correction would be made by tightening the right-side spokes a quarter turn each and loosening the left-side spokes a quarter turn each.
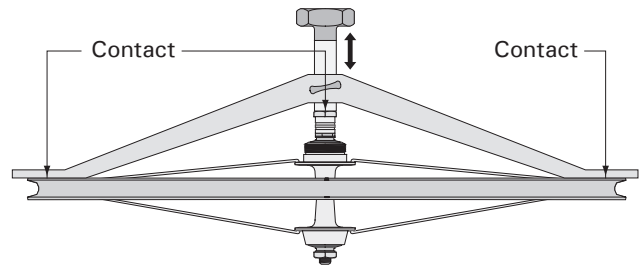
Dish and lateral errors

Lateral error and dish error are closely related. As mentioned in pitfall #5, useful information about dish cannot be determined when the wheel has significant lateral errors. At the conclusion of the radial-error corrections, lateral errors were checked and cleaned up as necessary, so at this point the wheel is ready for the initial dish observation. Once a dish correction is made, check the lateral again (and correct if necessary) before re-checking the dish.
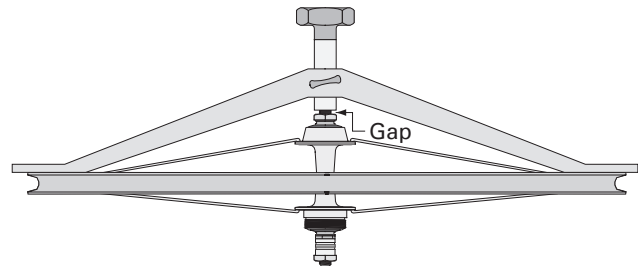
Measuring dish error

To determine the amount of dish error, use a tool called a dish gauge. The dish gauge rests on the rim at two points 180° apart, and then an adjustable part is set to contact the face of the locknut on the axle, so that the tool is contacting the wheel at three points (two on the rim and

one on the hub). Theoretically, the tool can be initially set on either side of the wheel; for the purposes of simplicity and clarity, the following discussion assumes that the dish tool has been set for three-point contact on the right side of the wheel.
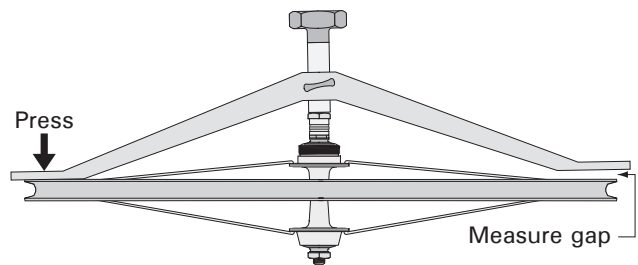

17.16 Adjust the dish tool to have three-point contact.

Next, the tool is transferred to the left side of the wheel. At random, one of three conditions might be found. The tool might contact at three points, indicating no dish correction is needed. Second, when the dish tool is held down against the rim at one end, it contacts at the hub but has a gap at the other point on the rim (180° away). In this case, the gap should be measured (with feeler gauges) and perhaps corrected. The last possibility is that the tool might contact the rim at two points but has a gap at the hub. There is an error that needs to be measured and perhaps corrected, but not until the tool is reset on the left side of the wheel for three-point contact and transferred back to the right side so that the error can be measured at a gap at the rim.

17.17 A gap seen at the hub after transferring the tool to the second side. Reset the tool and transfer back to the other side.

17.18 Measure the gap between the end of the dish tool and the rim.

Whether to measure dish error at hub or rim

The last condition of resetting the tool and transferring back to the right side needs to be explained. Error can legitimately be measured either at the gap at the rim or at the gap at the hub. (When referring to gap at the rim, it always means that with one end of the tool held to the rim there is gap at the other end of the tool.) Two things change, in either case.

If the gap is at the *rim* (on the left, for example) and spokes will be *tightened*, they will be tightened on the *same* side of the wheel (left side, in this case). If the gap is at the left side of the *rim* and spokes will be *loosened*, they will be loosened on the *opposite* side of the wheel (right side, in this example). If the gap is at the *hub* (on the left, for example) and spokes will be *tightened*, they will be tightened on the *opposite* side of the wheel (right side, in this case). If the gap is at the left side of the *hub* and spokes will be *loosened*, they will be loosened on the *same* side of the wheel (left side, in this case).

Additionally, for a given amount of dish error, the gap seen at the hub will always be half the size of the gap at the rim when the tool is transferred to the other side. Use a formula (described in the next paragraph and built into the procedure) to convert gap size to the size (number of turns) of the correction. If the formula is designed to be correct for converting gap-at-rim to turns-of-correction, then it will be wrong for converting gap-at-hub to turns-of-correction.

The formula for converting gap-at-rim to turns-of-correction is simply to divide the size of the gap by eight (if gap is measured in millimeters). For example, an 8mm gap measured at the rim on the right side would be corrected by turning all the nipples on one side one whole turn (8÷8=1). If the wheel were in need of tightening, it would require a whole turn on the right. If it were in need of loosening, it would be a whole turn on the left. Whether to tighten or to loosen all the nipples is determined by the existing spoke tension.

Consider two more examples. There is a 5mm gap on the right side. Divide 5mm by eight and the answer is .625. Should the correction be 625 thousandths of a turn on each nipple? No, too complicated. The number .625 is exactly halfway between .500 (one half) and .750 (three quarters). Quarter-turn increments are the smallest ones that should be used when adjusting nipples to correct dish. What should you do in this example, one half turn or three quarter turns? Be conservative and err on the side of caution by going with one half turn. On the other hand, if you divided the gap by eight and got

.718 (for example), definitely go with three quarter turn nipple adjustments.

Fixing dish errors

To fix dish, set the dish tool so that a gap is found between one end of the tool and the rim on the side of the wheel opposite from where the tool had perfect three-point contact. Second, measure the gap and divide by eight (gap in millimeters) and round the answer to the nearest quarter-turn increment to determine the size of the nipple adjustments. Third, measure the tension in order to know whether to tighten or loosen nipples when correcting dish (see page 17-8). Make the adjustment by either tightening the nipples on the same side of the wheel as where the dish tool showed a gap to the rim or by loosening the nipples on the other side of the wheel.

38. [ ] Set dish tool to have three-point contact on right side of wheel.

39. [ ] Transfer dish tool to left side of wheel. Check one of following:
    [ ] Gap at rim is 0–2mm, proceed to step 52.
    [ ] Gap at rim is >2mm, proceed to step 42.
    [ ] Gap is seen at the hub.

40. [ ] **If gap is seen at hub:** Set dish tool to have three-point contact on left side of wheel.

41. [ ] **If gap is seen at hub:** Transfer dish tool to right side of wheel. Gap will now be found at rim; proceed to step 42.

42. [ ] **If gap is seen at rim:** With one end of dish tool held to rim, measure gap at other end and record gap here: _____ on *Left side Right side* (circle one) (If <2mm, go to **SETTING FINAL TENSION**.)

43. [ ] **If gap is seen at rim:** Divide number in step 42 by eight and round answer to nearest quarter. This number is necessary turns of correction for nipples.
    Record here: _____ turn(s) of nipples

Before making the dish correction, determine the wheel tension in order to know whether to tighten or loosen when correcting dish. The acceptable tension range for a wheel is 80–120kgf, with ideal being about 100kgf. If the existing tension is anywhere under 90kgf, nipples should be tightened (unless the size of the correction is going to be a whole turn or more, in which case it should be split into a correction in which spokes on one side of the wheel are tightened and the other side are loosened). If the tension is between 90–100kgf, loosen all the spokes on one side by half the necessary correction and tighten all the spokes on the other side by half the necessary correction. If the existing tension is anywhere over 100kgf, loosen nipples for the dish correction.

44. [ ] Measure tension on ten consecutive right-side spokes (left on front disc), record readings in following blanks, and total.

_____ + _____ + _____ + _____ + _____

_____ + _____ + _____ + _____ + _____ = _____

45. [ ] Divide step 44 total by 10   ÷ 10
    Average reading is: = _____

46. Look up average reading on tensiometer chart and read across to column for spoke gauge used on wheel. Decide whether tension is: (check one choice)
    [ ] <80kgf & step 43 is ≤1(tighten nipples)
    [ ] 80–100kgf *or* step 43 is >1 (split, one side tighten, other side loosen)
    [ ] >100kgf (loosen nipples)

47. Based on step 46, dish correction should be:
    [ ] Tighten nipples
    [ ] Split, loosen one side and tighten other
    [ ] Loosen nipples

In step #48, one of three choices will be checked, then the blank in the checked choice should be filled in. Check the same choice as was checked in step #47 (for example, if "[ ] Tighten..." was checked in step #47, check "[ ] Tighten..." in step #48). The blank in the checked choice should be filled in with the value that was calculated in step #43. After checking off a choice and filling in the blank, circle the notation **left** or **right** in the checked choice in step #48. Wherever the option checked is "tighten," circle the **left** or **right** choice to match whether **Left side** or **Right side** was circled in step #42. Wherever the option checked is "loosen," circle the **left** or **right** choice to be the opposite of whether **Left side** or **Right side** was circled in step #42.

48. Check one of following choices, based on whether to tighten, split, or loosen spokes (determined in step 47). If tightening, always tighten on same side of wheel as gap was found at rim; if loosening, always loosen on opposite side of wheel from where gap was found at rim (determined in step 42). Fill in blank in checked option with amount calculated in step 43:
    [ ] Tighten on *left   right* **(circle one)**
        by _____ turns of nipples.
    [ ] Split, loosen on *left   right* **(circle one)**
        by _____ turns of nipples
        and tighten on *left   right* **(circle one)**
        by _____ turns of nipples.
    [ ] Loosen on *left   right* **(circle one)**
        by _____ turns of nipples.

49. [ ] Perform correction described in step 48, turning nipples as uniformly as possible.

50. [ ] Check and correct lateral errors until largest gap is <.5mm.

51. [ ] Check with dish tool for size of gap at rim again. If gap is ≤2mm go to **SETTING FINAL TENSION**. If >2mm, repeat steps 38–51.

SETTING FINAL TENSION

Even after all this, the wheel's average tension might still be too low, or it might be too high. The tension is important because low tension causes premature spoke fatigue and unstable true. High tension causes fatigue cracks in the rim and increases the likelihood of a complete wheel collapse.

The acceptable tension range for conventional wheels is very broad, about 80–120kgf. Some rim and wheel manufacturers make specific tension recommendations. The general conditions that lead to a need for setting spoke tension in the lower half of the range (80–100kgf) are:

> Front wheels
> Lightweight rider
> Extreme lightweight rims
> Poor nipple condition

The general conditions that lead to a need for setting spoke tension in the higher half of the range (100–120kgf) are:

> Rear wheels with pronounced dish
> Heavyweight riders
> Extreme heavy-duty usage

Table 17-2 includes several manufacturers' tension recommendations.

TENSION RECOMMENDATIONS (table 17-2)

Wheel brand: Model	Tension range (location)
Campagnolo: Eurus	60–80kgf (front) 95–113 (rear right)
Campagnolo: Hyperon, Neutron, Proton	60–70kgf (front) 120–140kgf (rear right)
Campagnolo: Scirocco	60–80kgf (front) 85–105kgf (rear right)
Campagnolo: Zonda	70–85kgf (front[1]) 90–110kgf (rear right)
Mavic: all wheels	90–110kgf (front) 90–110kgf (rear right)
Shimano: 16-spoke	100–120kgf (front) 107–130kgf (rear right)

[1] Front wheel has radial spokes alternating with tangential spokes that consistently alternate higher tensions (radial spokes) and lower tensions (tangential spokes) with a 15kgf difference.

Wheels with a deep-V rim cross-section and low spoke count (under 28 spokes on a wheel in the 700C or 26" size ranges) generally require high tensions. Always

pursue recommendations from the rim or wheel manufacturer for these types of wheels. In the absence of the availability of such recommendations, tighten rear-wheel right-side spokes to 120–130 kgf. This may still be low for some of these wheels, but using higher tensions than this without specific manufacturer recommendations puts the mechanic in the position of assuming the risk of sudden catastrophic wheel failure. Tensions lower than ideal only risk premature spoke breakage.

52. [ ] Measure tension on ten consecutive right-side spokes (left on front disc), record readings in following blanks, and total.

_____ + _____ + _____ + _____ + _____

_____ + _____ + _____ + _____ + _____ = _____

53. [ ] Divide step 52 total by 10 ÷ 10
    Average reading is: = _____

54. [ ] Look up average reading on tension-meter chart and read across to column for spoke gauge used on wheel.
    Write approximate kgf here: _____ kgf

Table 17-3 provides general guidelines for the size of the tension correction needed to arrive close to the target tension of 95–120kgf. It is not unusual to make the recommended correction from table 17-3 and still need an additional small correction (either way).

Table 17-2 (page 17-18) includes manufacturer-specific tension guidelines that should supersede the generic tension guidelines of this chapter.

FRONT-WHEEL TENSION CORRECTIONS (table 17-3a)

KGF Value	Tighten all nipples
not on chart	1 ¼ turn (all spokes)
<55	1 turn (all spokes)
55−79	¾ turn (all spokes)
80−89	½ turn (all spokes)
90−94	¼ turn (all spokes)
95−120	finished setting tension
>120	**LOOSEN** ¼ turn (all spokes)

REAR-WHEEL TENSION CORRECTIONS (table 17-3b)

KGF Value	Tighten left nipples	Tighten right nipples
<55	¾ turn	1 ¼ turn
55−79	½ turn	1 turn
80−89	½ turn	¾ turn
90−94	¼ turn (all spokes)	
95−120	finished setting tension	
>120	**LOOSEN** ¼ turn (all spokes)	

Note that when a tension correction in excess of one half turn is recommended for a rear wheel, a different size of correction is recommended for the right-side and left-side spokes; due to the flatter angle on right-side rear-wheel spokes, the rim tends to respond less to the correction on that side. If this is ignored, then the rim tends to lose its dish adjustment as the tension is increased. The compensation for this recommended in table 17-3 is approximate. The accuracy of the compensation is affected by how close the wheel is to perfect dish before adding the tension and by how flat the right-side spoke angle is when the wheel is correctly dished.

55. [ ] Find kgf value in table 17-3 and record corresponding correction here:
    Left-side turns   Right-side turns
    _____   _____

56. [ ] Perform adjustment indicated in step 55 on all nipples.

57. [ ] Check and adjust lateral error until largest gap is <.5mm.

58. [ ] Check and correct dish error as described in steps 38 through 51, if gap at rim is >2mm.

59. [ ] Measure tension on ten consecutive right-side spokes (left on front disc), record readings in following blanks, and total.

_____ + _____ + _____ + _____ + _____

_____ + _____ + _____ + _____ + _____ = _____

60. [ ] Divide step 59 total by 10 ÷ 10
    Average reading is: = _____

61. [ ] Look up average reading on tension-meter chart and read across to column for spoke gauge used on wheel.
    Write approximate kgf here: _____ kgf

62. [ ] Find kgf value in table 17-3 and record corresponding correction here:
    Left-side turns   Right-side turns
    _____   _____

63. [ ] Perform adjustment indicated in step 62 on all nipples.

64. [ ] Check and adjust lateral error until largest gap is <.5mm.

65. [ ] Check and correct dish error as in described steps 38 through 51, if gap at rim is >2mm.

66. [ ] Measure tension on ten consecutive right-side spokes (left on front disc) record readings in following blanks, and total.

_____ + _____ + _____ + _____ + _____

_____ + _____ + _____ + _____ + _____ = _____

67. [ ] Divide step 66 total by 10 ÷ 10
    Average reading is: = _____

68. [ ] Look up average reading on tension-meter chart and read across to column for spoke gauge used on wheel.
    Write approximate kgf here: _____ kgf

69. [ ] Find kgf value in table 17-3 and record corresponding correction here:
    Left-side turns   Right-side turns
    _____   _____
70. [ ] Perform adjustment indicated in step 69 on all nipples.
71. [ ] Check and adjust lateral error until largest gap is <.5mm.
72. [ ] Check and correct dish error as described in steps 38 through 51, if gap at rim is >2mm.
73. [ ] Measure tension on ten consecutive right-side spokes (left on front disc) record readings in following blanks, and total.

    _____ + _____ + _____ + _____ + _____

    _____ + _____ + _____ + _____ + _____ = _____
74. [ ] Divide step 73 total by 10   ÷ 10
    Average reading is: = _____
75. [ ] Look up average reading on tension-meter chart and read across to column for spoke gauge used on wheel.
    Write approximate kgf here: _____kgf
76. [ ] Find kgf value in table 17-3 and record corresponding correction here:
    Left-side turns   Right-side turns
    _____   _____
77. [ ] Perform adjustment indicated in step 76 on all nipples.
78. [ ] Check and adjust lateral error until largest gap is <.5mm.
79. [ ] Check and correct dish error as described in steps 38 through 51, if gap at rim is >2mm.
80. [ ] Repeat steps 73 through 79 as many times as necessary until tension is 95–120kgf.

TENSION-BALANCING SPOKES

Theory

In taking the readings to determine the tension average, it will probably be observed that the spokes on one side of the wheel vary wildly in tension. Variations in readings are within acceptable limits if they vary by the equivalent of ±20kgf and would be considered excellent at the equivalent of ±10kgf.

When spoke tension needs balancing, there will be excessively tight spokes and excessively loose spokes. Both conditions cause problems.

High-tension:
    High-tension spokes cause localized stress at the rim at each nipple hole, which can lead to rim failure.
    High-tension spokes are much more likely to lead to nipple failure (rounded wrench flats) than spokes under normal tension, particularly if the overall tension is near its upper limit and/or the spoke and nipple quality is low.
    High-tension spokes twist (called *wind-up*) more while truing the wheel and lead to more work when stressing the wheel to eliminate wind-up.

Low-tension:
    Low-tension spokes fatigue more quickly because they tend to go slack when they are at the bottom of the loaded wheel, leading to a "snap" effect when they return to tension.
    Low-tension spokes are more likely to have their nipples unwind, leading to loss of true.
    Low-tension spokes limit the potential to true errors by loosening spokes. This is particularly true when working with the left side of a rear wheel with exaggerated dish.

The tension-balancing process is a good diagnostic tool. During the process, a normal wheel will have some spokes that have a high tension and others that have low tension. If the wheel is not damaged, these high- and low-tension spokes will virtually always be present as adjacent pairs. The process of correction is to find a high and a low spoke that are adjacent and adjust one down and the other up. When many consecutive high-tension spokes are found (and the wheel is true) it indicates rim damage. The same is true when there are multiple consecutive low-tension spokes.

Three procedure alternatives

There are three ways to tension-balance wheels.

The first method, *preventative balancing*, is informal and imprecise but reasonably effective. It is incorporated into the lateral-true procedure described earlier. All it consists of is checking two adjacent spokes for relative tension when deciding which one of them to use to correct a lateral error.

The second method, *reading balancing*, has a detailed procedure starting with step #81 (page 17-22). With this method, an average reading based on all the spokes on one side of the wheel is determined and a simple mathematical formula is applied to the average to determine the acceptable reading range. Spokes outside the range are then adjusted. This method works well on spokes of common thickness in wheels that are near a 100kgf average but is less applicable to wheels with very thin spokes or very low or high average tensions.

The third method, *precision balancing*, is described at the end of the whole wheel-truing process under the heading **PRECISION TENSION BALANCING** (page 17-26). This method is the most precise but is very time consuming and has some complicated mathematical procedures. This method is the best one to use if the spokes are a thin gauge or the tensions are near the limits of the acceptable range.

Reading balancing with a Wheelsmith Tensiometer

Steps #85–#89 and #103–#107 use the *reading balancing* method of determining the acceptable range. This method is only suitable if a Wheelsmith Tensiometer is being used and the average tension is 80–100kgf. The reason for this tension limitation is that there is not a direct linear comparison between reading values and kgf values on the tension-meter chart. If the tension is 80–100kgf, then reading balancing can be done by adding and subtracting 3 from the average reading and rounding the result to the nearest increment of 2.5 (*plus-3/minus-3* method).

For example, consider a wheel with 2.0mm spokes and an average tension reading of 72. Using the plus-3/minus-3 method of determining the acceptable-reading range, the result would be a reading range of 70 to 75. Looking these values up on the example tension-meter chart on page 17-10, a tension range of 89–104kgf is determined. The average reading of 72 equals 95kgf; the tension range of 89–104kgf is well within the recommended ±10kgf range of the 95kgf average.

If the average tension is above 100kgf, the *plus-3/minus-3* method will create a tension range that is too wide to achieve the desired properties of rim durability and true stability (unacceptable spoke tensions will be left alone). If on the same wheel with 2.0mm spokes the spoke tension averaged 110kgf, the average reading would be 76.25. Using the plus-3/minus-3 method of determining the acceptable reading range, the result would be a reading range of 72.5–80. Looking these readings up on the same chart, it is apparent that a tension range of 96.5–127kgf results. This range is –13.5kgf to +17kgf of the 110kgf average tension for this wheel. This is well outside of the recommended ±10kgf range. This discrepancy is why the alternate *precision tension-balancing* method involves so much math. Using the *precision tension-balancing* method would determine an acceptable reading range of 72.5–77.5 for the same wheel at 110kgf. This reading range would result in something much closer to ±10kgf recommendation.

If the average tension is below 80kgf, the *plus-3/minus-3* method will create an unacceptable tension range that is too narrow (spokes with acceptable tensions will be adjusted unnecessarily). If on the same wheel with 2.0mm spokes the spoke tension averaged 75kgf, the average reading would be 63.9. Using the *plus-3/minus-3* method of determining the acceptable reading range, the result would be a reading range of 60.0–67.5. Looking these readings up on the same chart, it is apparent that a tension range of 68–83kgf results (–7kgf/+8kgf of the 75kgf average tension). This is well within the recommended ±10kgf range; spokes within this range are pointless to balance.

This discrepancy is why the alternate *precision tension-balancing* method involves so much math. Using the *precision tension-balancing* method would determine an acceptable reading range of 57.5–67.5 for the same wheel at 75kgf. This reading range would result in something much closer to ±10kgf recommendation.

If the *plus-3/minus-3 reading balance* method is used when tensions are outside the 80–100kgf range, it is quite likely that time will be spent trying to balance spokes that are acceptable or some spokes that need balancing will not be balanced.

Following are some examples that show that using the *plus-3/minus-3 reading balancing* method will create an acceptable reading range that will be either 5 or 7.5. To calculate the acceptable reading range, add and subtract 3 from the average reading to determine the minimum and maximum acceptable readings. Round these two answers to the nearest 2.5 reading increment value. The two numbers that result from the rounding are the minimum and maximum acceptable readings and should range from 5 to 7.5 reading units.

For example, if the average reading is 70.2:

70.2 + 3 = 73.2 (round to 72.5)

70.2 – 3 = 67.2 (round to 67.5)

See in this example that the average reading is close to halfway between the minimum and maximum readings (2.3 below 72.5 and 2.7 above 67.5). The resulting acceptable reading range is 5 reading units.

For another example, if the average reading is 71.3:

71.3 + 3 = 74.3 (round to 75)

71.3 – 3 = 68.3 (round to 67.5)

See in this second example that the average reading is close to halfway between the minimum and maximum readings (3.7 below 75 and 3.8 above 67.5). The resulting acceptable reading range is 7.5 reading units. Had a 5-unit reading range been used in this case (70 to 75), then the average would not be close to halfway between the minimum and maximum readings, making the mechanical process of correcting the unbalanced pairs more challenging.

This method, in summary, requires picking an acceptable reading range that has the average reading close to halfway between the minimum and maximum readings. Ideally this range would be 5, but if necessary it would be 7.5. Any reading range (when using a Wheelsmith Tensiometer) of 10 or more would usually be considerably more than a ±10kgf range and in some cases more than ±20kgf.

Determine right-side acceptable reading range

The following procedure only applies if using a Wheelsmith Tensiometer.

NOTE: If not tension balancing the wheel, go to step 117.

81. [ ] Measure tension of all spokes on right side of wheel and record readings on right face of rim adjacent to each spoke.

82. [ ] Add all right-side readings together and record right-side total here: _____

83. [ ] Divide by number of readings: ÷ ____
84. [ ] Right-side average reading is: = _____

NOTE: For a more precise alternative for determining the minimum and maximum readings than the method in steps 85–89, use steps 1–37 of the PRECISION TENSION BALANCING procedure.
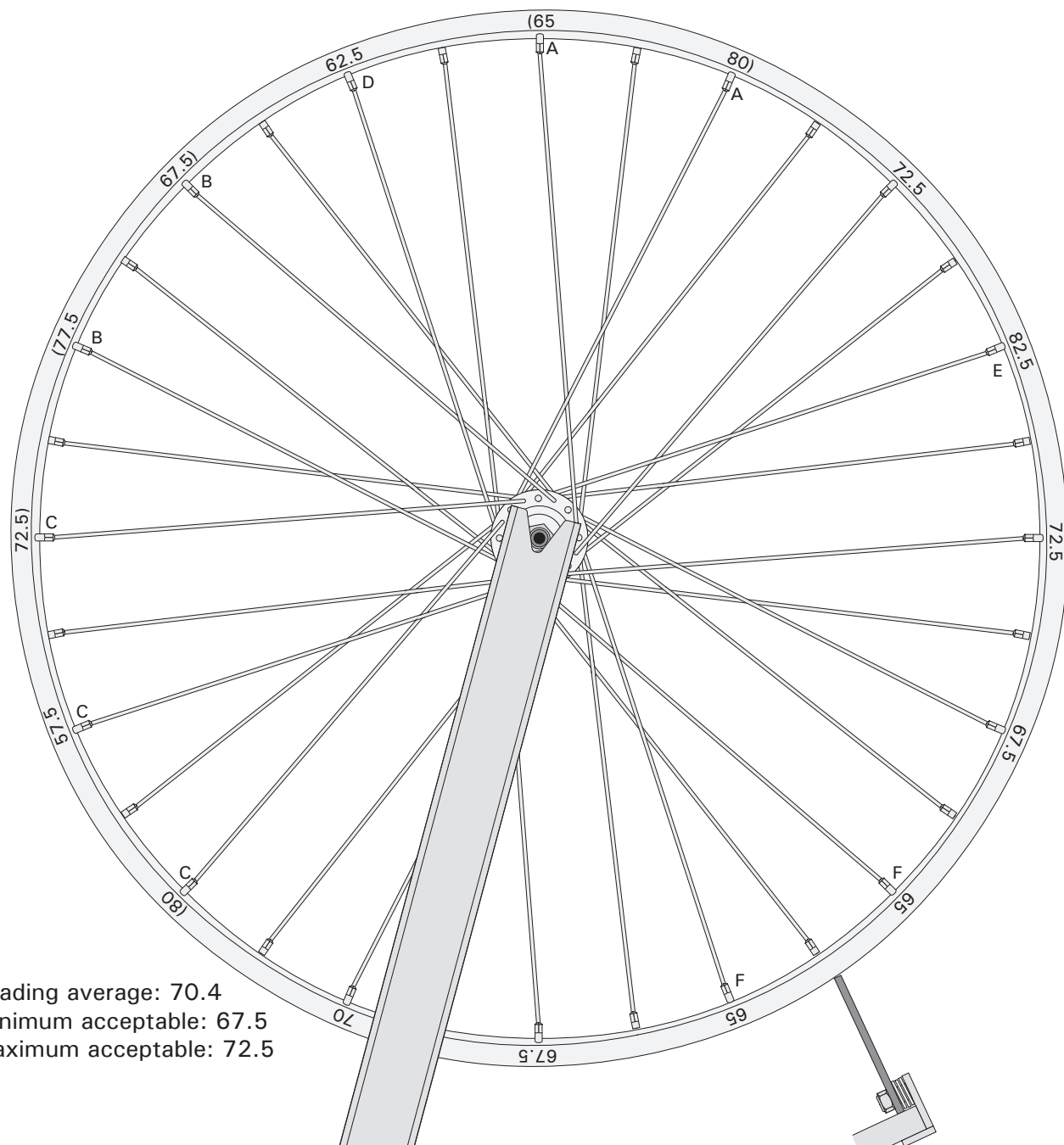
85. [ ] Range reduction: −3
86. [ ] Right-side MINIMUM READING: = _____
87. [ ] Repeat step 84: _____
88. [ ] Range increase: +3
89. [ ] Right-side MAXIMUM READING: = _____

Reading average: 70.4
Minimum acceptable: 67.5
Maximum acceptable: 72.5

17.19 This rim has been marked with tension readings for all the spokes on this side. Pairs suitable for balancing are bracketed. See the above text for a detailed explanation.

Examine the tension markings on the rim for sets of "high/low" spokes. A high/low set would be two consecutive spokes at the rim from the same flange in which one spoke was higher than the acceptable reading range calculated and the other was either unacceptably low or in the low side of the acceptable range. Or, it could be one spoke that was unacceptably low and the adjacent spoke was in the high side of the acceptable range. Mark these pairs by drawing bracket marks on the face of the rim that include the pair of high/low-tension readings.

It is possible to find isolated single spokes that are high or low tension, and there are no apparent spokes next to them to balance with the high- or low-tension spoke. These isolated unbalanced spokes indicate either a truing error in the wheel at that point or a defect or damage point in the rim. If it is a new rim that is precisely trued, this might be grounds for seeking warranty satisfaction.

If the wheel is true and there are multiple consecutive high-tension or low-tension spokes, it is a sure sign of rim damage.
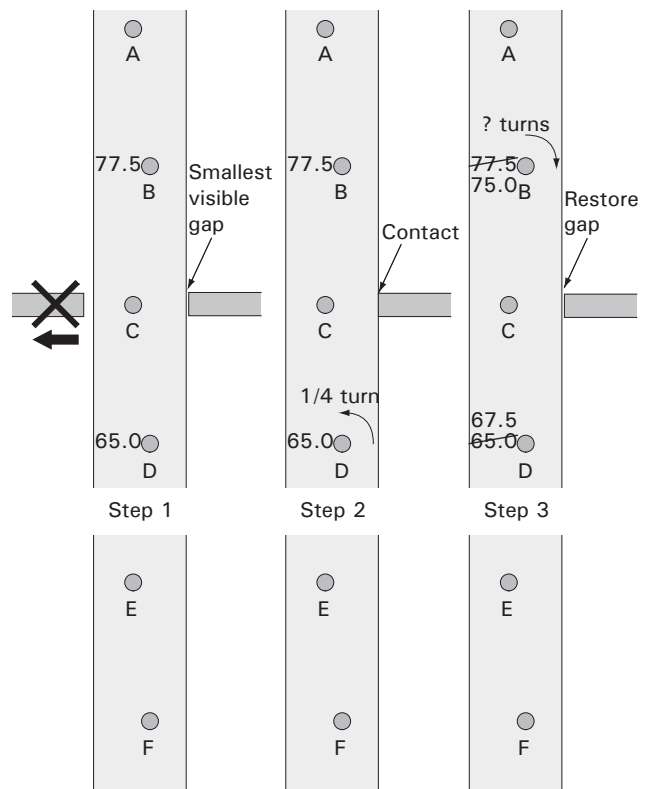
In figure 17.19 (page 17-22), a wheel has had the tension readings written on the face of the rim and pairs (marked A, B, and C) have been selected for balancing. The reading marked D is an isolated low-tension spoke that cannot be balanced. The reading marked E is an isolated high-tension spoke that cannot be balanced. The group marked F is a group of consecutive low-tension spokes that indicate a rim defect if both the lateral and radial true are good at that point.

Correcting right-side tension-balance errors

A high/low pair of adjacent, same-side spokes can be balanced because the spokes have overlapping zones of influence on the rim. Two adjacent spokes on the same side of the wheel both influence the lateral true at the halfway point between the spokes. If a lateral-true indicator on the truing stand is set to almost contact the rim at this halfway point, and the low-tension spoke on one side of the true indicator is tightened a quarter turn, then when the high-tension spoke on the other side is loosened the true can be restored at the halfway point. Tension of both spokes has been maintained, and the lateral true halfway between them has been maintained. See figure 17.20 for graphic examples of how to tension balance a pair of spokes.

90. [ ] Bracket pairs of spokes on wheel that need balancing.
91. [ ] Select pair to balance.

17.20 In this example, spokes B and D need to be balanced. Step 1) Eliminate the left true indicator and set the right true indicator to the smallest visible gap. Step 2) Turn nipple D 1/4 turn counterclockwise. The indicator should contact. Step 3) Turn nipple B clockwise just until the original gap is restored, then mark new tensions for spokes B and D.

92. [ ] Cancel out lateral-true indicator on left side of wheel.
93. [ ] Set right-side indicator to just barely clear rim at point halfway between spokes being balanced.
94. [ ] Tighten looser of two spokes being balanced 1/4 turn. Observe clearance at point halfway between spokes disappear.
95. [ ] Loosen tighter of two spokes being balanced just enough to restore initial clearance set at point halfway between two spokes being balanced.
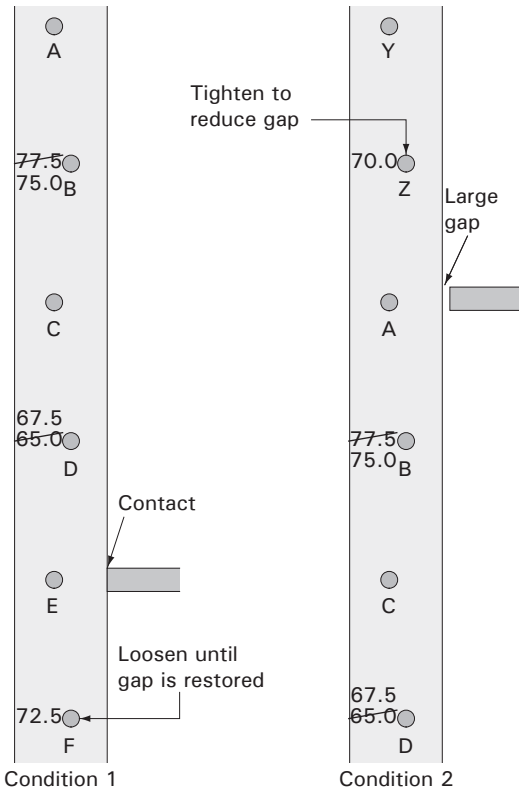96. [ ] Measure new tensions on spokes being balanced and repeat steps 93–95 if necessary.

Even though true has been maintained at the point halfway between the spokes, there is a chance that the true has been lost just outside the zone between the two spokes.

Check to see if more than one spoke might potentially be used to correct the lateral error. Remember, depending on the lateral stiffness of the rim, each spoke can affect an area 3–5" in each direction. The spoke that will be used to correct the lateral error will be on the same side of the rim as the ones that are being tension balanced.

To correct the lateral error that has developed, choose whichever spoke has the most appropriate tension level to allow further loosening or tightening, as the case may be. See the illustration below.

17.21 **Condition 1:** When lateral true is checked at E after balancing B and D, a contact is found at E. Since F is tighter than D, loosen F to eliminate the contact. **Condition 2:** When lateral true is checked at A after balancing B and D, an excessive gap is found. Since Z is looser than B, tighten Z to fix the gap.

97. [ ] Once both spokes have tension in acceptable range, check true just outside of balance zone on both sides. Correct true by finding closest spoke *with suitable tension* that will affect lateral in area in need.
98. [ ] Repeat steps 91–97 for all other pairs bracketed on right side of wheel.

Left-side acceptable reading range
99. [ ] Measure tension of all spokes on left side of wheel and record readings on left face of rim adjacent to each spoke.
100. [ ] Add all left-side readings together and record left-side total here: _____
101. [ ] Divide by number of readings: ÷ ____
102. [ ] Left-side average reading is: = _____
103. [ ] Range reduction: −3
NOTE: For a more precise alternative for determining the minimum and maximum readings, use steps 1–37 of the PRECISION TENSION BALANCING procedure.
104. [ ] Left-side MINIMUM READING: = _____

105. [ ] Repeat step 102: _____
106. [ ] Range increase: +3
107. [ ] Left-side MAXIMUM READING: = _____

Correcting left-side errors
108. [ ] Bracket pairs of spokes on wheel that need balancing.
109. [ ] Select pair to balance.
110. [ ] Cancel out lateral-true indicator on right side of wheel.
111. [ ] Set left-side indicator to just barely clear rim at point halfway between spokes being balanced.
112. [ ] Tighten looser of two spokes being balanced 1/4 turn. Observe clearance at point halfway between spokes disappear.
113. [ ] Loosen tighter of two spokes being balanced just enough to restore initial clearance set at point halfway between two spokes being balanced.
114. [ ] Measure new tensions on spokes being balanced and repeat steps 111–113 if necessary.
115. [ ] Once both spokes have tension in acceptable range, check true just outside of balance zone on both sides. Correct true by finding closest spoke *with suitable tension* that will affect lateral in area in need.
116. [ ] Repeat steps 109–115 for all other pairs bracketed on left side of wheel.

STABILIZING THE TRUE

While the nipples were being tightened, some of the spokes have been turning with them (wind-up). When the bike is ridden, the spokes will all unload temporarily and will unwind to varying degrees. The unloading effects the lateral true. The common signal that this is happening is one or several sounds coming from the wheel when it is first ridden after truing, which then go away.

There are several techniques for stabilizing wheel true. Two are safe but ineffective, one is safe and effective but inefficient, and one is risky but effective and efficient.

One safe and ineffective technique is often seen in books. It consists of slightly over-tightening a nipple and then backing off some. Although this technique works in principle, there is no correct amount of over-tightening and backing off that works every time.
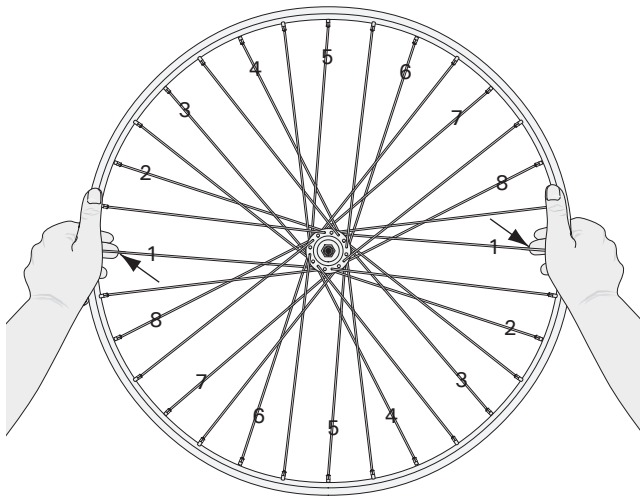
The other safe but ineffective method is to squeeze parallel pairs of spokes on each side of the wheel once the truing is completed. After using this method, spokes still ping on the first test ride, and the wheel still goes out of true.

A safe, effective, and inefficient method is to simply test-ride the wheel after truing it. Follow this up with another ride and another re-true if necessary. Then another, if necessary. It could take up to three or four cycles of installing the wheel on the bike, riding, remov-

ing the wheel, and re-truing before the true is stabilized. Another version of this is to put some sort of vertical load on the wheel at the axle or at the top of the rim. Experimentation with this shows that it is only partially effective. The wheel will still ping and go out of true some once ridden.

The risky but effective technique is to side load the wheel. The wheel is supported at the axle and pressed down simultaneously at two points 180° apart at the rim. This is done repeatedly on both sides of the wheel until all the spokes have been momentarily relieved of tension. What makes this effective is that the wheel has very little lateral strength so it is easy to deflect the rim enough to successfully unload a spoke. It is this very thing that makes this technique risky. The lateral weakness of the wheel, combined with careless technique, can result in a collapsed wheel.

To safely side load a wheel, the tension must not be to high. This technique should never be used when a tension meter has not been used to confirm the average right-side tension is below 120kgf. Additionally, it is important to use several forms of feedback to be able to tell when just enough load has been applied. The feedback might be a noise from a spoke, a twitching sensation felt in a spoke, or any sensation that the rim is deflecting. *Whichever form of feedback occurs first indicates that the wheel has been adequately loaded at that point!*

17.22 To stress the wheel, center the balls of your thumbs over two spokes from the bottom flange that are 180° apart. Reach from below to place a finger against each spoke. Press firmly until you hear or feel a spoke unwind. Repeat for sets 2–8, then repeat on other side of wheel.

The correct technique to side load the wheel is to place it on a solid surface that is low enough to be able to lean over it. Protect the surface from the axle by using a small block of wood. Place a hand at the 3 o'clock position on the rim and a hand at the 9 o'clock position on the rim. At both positions, the hand should be centered over a spoke that comes from

the lower flange, and a finger should wrap around the outside of the rim and touch the lower-flange spoke. This finger is critical because it is used to feel for any twitch in the spoke that indicates the side-load level is enough (see figure 17.22). With elbows locked, shove gently down on the rim and be sensitive to the ping sound, a spoke twitch, or the feeling of the rim deflecting. If nothing is felt, shove a little harder. If the rim seems to suddenly give way, break loose the locked elbows *immediately*.

117. [ ] Place wheel right-side down on low surface.
118. [ ] Position hands 180° apart on rim with hands centered over spokes coming from low flange and fingers touching same spokes.
119. [ ] With locked elbows, gently shove against rim until ping, spoke twitch, or rim flex is experienced. Increase effort if no sounds, twitch, or flex is encountered.
120. [ ] Move hands to adjacent spokes from lower flange and repeat step 119. Repeat until all spokes from lower flange have been unloaded.
121. [ ] Turn wheel over and repeat steps 118–120 for second side.
122. [ ] Check if lateral-true error exceeds maximum allowed.

Side loading eliminates spoke wind-up. Spoke wind-up was created by tightening nipples. If nipple tightening is used to eliminate lateral errors that appear after side loading, then the wind-up will be reintroduced. Therefore, when correcting these lateral errors, the best technique is to loosen a spoke that is on the same side of the wheel as the lateral-true indicator that is contacting the rim. For example: If the contact is on the right side of the rim, loosen the right-side spoke that is closest to the center of the contact. Loosening will not create as much wind-up as tightening.

123. [ ] Correct lateral-true errors if necessary by **loosening spoke(s)** at point of contact coming from same side of hub as side that is contacting. **NOTE: Wheel will not stabilize if spoke are tightened—all corrections must be by loosening!**
124. [ ] Repeat steps 117–123 repeatedly until wheel remains within desired lateral tolerance. (When spokes are adjusted on one side only, side loading need only be done with that side down.)

Post-truing completion

125. [ ] Re-adjust hub as necessary. (Remember, a properly adjusted quick-release, conventional-bearing hub has play when out of bike, which had to be eliminated to true wheel.)
126. [ ] Reinstall tire, quick-release skewer, and wheel in bike.
127. [ ] Clean rim of any oily residues left over from truing process.

PRECISION TENSION BALANCING

Precision balancing is a more precise way to determine the acceptable tension-reading range for a given side of a wheel. This procedure is an alternative to steps #85–89 or #103–107 (pages 17-22 and 17-24) of the **TRUING WHEELS WITH UNDAMAGED RIMS, SPOKES, AND NIPPLES** procedure. This procedure is preferred if limitations of the wheel require that the average tension be outside the recommended 80–100kgf range or if more precision is desired. For most wheels, the *reading-balancing* method is adequate. The *precision tension-balancing* method requires more time and more math.

The *precision tension-balancing* process consists of four basic steps. Each step is a mathematical calculation. The first step is to convert the average reading from the wheel into an exact tension average. Because the tension-meter chart has relatively large jumps between values in the reading column, when the average reading falls between two readings that appear on the chart, a mathematical process called "interpolation" is needed to determine the tension value that is equivalent to the average reading. The second step is to determine an acceptable tension range for the wheel. This is accomplished by adding 10 to the average tension to determine that maximum tension and by subtracting 10 from the average tension to determine the minimum tension. The last two steps of the process use the process of interpolation to convert the maximum and minimum acceptable tensions to minimum and maximum acceptable reading values. Once the process of calculating the minimum and maximum acceptable reading values is completed, then the wheel can be reviewed for spokes that fall outside the acceptable range.

The maximum reading value (X), determined in the following process, can be used in steps #89 or #107 (pages 17-22 and 17-24), and the minimum reading value (y), determined in the following process, can be used in steps #86 or #104 (pages 17-22 and 17-24) of the **TRUING WHEELS WITH UNDAMAGED RIMS, SPOKES, AND NIPPLES** worksheet. Step #1 gets its value from step #84 or #102 (pages 17-22 and 17-24) of the **TRUING WHEELS WITH UNDAMAGED RIMS, SPOKES, AND NIPPLES** worksheet.

Determining exact tension from average reading

By means of mathematical interpolation, steps #1 through #11 convert the average reading from the tension meter into a precise average tension (K).

1. [ ] Average of readings from one side
    (from step 84 or 102):   _____ A
2. [ ] Closest reading value < A from
    tension-meter chart *reading line*:   _____ B

3. [ ] Closest reading value > A from
    tension-meter chart *reading line*:   _____ C
4. [ ] Kgf value equal to B from
    tension-meter chart *kgf line*:   _____ D
5. [ ] Kgf value equal to C from
    tension-meter chart *kgf line*:   _____ E
6. [ ] A – B = F   _____ – _____ = _____ F
7. [ ] E – D = G   _____ – _____ = _____ G
8. [ ] F × G = H   _____ × _____ = _____ H
9. [ ] C – B = I   _____ – _____ = _____ I
10. [ ] H ÷ I = J   _____ ÷ _____ = _____ J
11. [ ] D + J = K   _____ + _____ = _____ K

Steps #6 through #11 can be expressed algebraically, which is easier for someone familiar with algebra. The formula is:

$$\frac{(A-B) \times (E-D)}{(C-B)} + D = K$$

Determining the acceptable tension range for tension balancing

Now that the precise average spoke tension has been determined, a simple process is used to determine the acceptable tension range.

12. [ ] Maximum tension in kgf (M)
    K + 10 = M   _____ + _____ = _____ M
13. [ ] Minimum tension in kgf (L)
    K – 10 = L   _____ – _____ = _____ L

Determining a tension reading equal to M

Steps #14 through #24 convert the maximum acceptable tension (M) from step #12 into an equivalent tension-meter reading (X) for the tension meter in use.

14. [ ] Maximum tension for this side: _____ M
15. [ ] Closest kgf value < M from
    tension-meter chart *kgf line*:   _____ N
16. [ ] Closest kgf value > M from
    tension-meter chart *kgf line*:   _____ P
17. [ ] Reading value equal to N from
    tension-meter chart *reading line*:   _____ Q
18. [ ] Reading value equal to P from
    tension-meter chart *reading line*:   _____ R
19. [ ] M – N = S   _____ – _____ = _____ S
20. [ ] R – Q = T   _____ – _____ = _____ T
21. [ ] S × T = U   _____ × _____ = _____ U
22. [ ] P – N = V   _____ – _____ = _____ V
23. [ ] U ÷ V = W   _____ ÷ _____ = _____ W
24. [ ] W + Q = X   _____ + _____ = _____ X

Steps #19 through #24 can be expressed algebraically, which is easier for someone familiar with algebra. The formula is:

$$\frac{(M-N) \times (R-Q)}{(P-N)} + Q = X$$

In the next step, the exact value of X needs to be rounded to a number that can actually be read from the

tension meter. The finest increments recommended earlier for reading a Wheelsmith Tensiometer are 0, 2.5, 5, and 7.5. Here are some examples.

Round anything from 58.8–61.2 to 60.0
Round anything from 61.3–63.7 to 62.5
Round anything from 63.8–66.2 to 65.0
Round anything from 66.3–68.7 to 67.5

The value determined in step #25 (page 17-15) is used in the **TRUING WHEELS WITH UNDAMAGED RIMS, SPOKES, AND NIPPLES** worksheet. Transfer the value to step #89 (page 17-22) of the wheel-truing worksheet (if tension balancing the right side of wheel) or to step #107 (page 17-24) of the wheel-truing worksheet (if tension balancing the left side of wheel).

25. [ ] Round X to nearest reading ending in 0, 2.5, 5, or 7.5 and record here:
MAXIMUM READING is: _____

Determining a tension reading equal to L

Steps #26 through #36 convert the minimum acceptable tension (L) from step #13 into an equivalent tension-meter reading (y) for the tension meter in use.

26. [ ] Minimum tension for this side: _____ L
27. [ ] Closest kgf value <L from
tension-meter chart *kgf line*: _____ n
28. [ ] Closest kgf value >L from
tension-meter chart *kgf line*: _____ p
29. [ ] Reading value equal to n from
tension-meter chart *reading line*: _____ q
30. [ ] Reading value equal to p from
tension-meter chart *reading line*: _____ r
31. [ ] L − n = s   _____ − _____ = _____ s
32. [ ] r − q = t   _____ − _____ = _____ t
33. [ ] s × t = u   _____ × _____ = _____ u
34. [ ] p − n = v   _____ − _____ = _____ v
35. [ ] u ÷ v = w   _____ ÷ _____ = _____ w
36. [ ] w + q = y   _____ + _____ = _____ y

Steps #31 through #36 can be expressed algebraically, which is easier for someone familiar with algebra. The formula is:

$$\frac{(L-n) \times (r-q)}{(p-n)} + q = y$$

In the next step, the exact value of y needs to be rounded to a number that can actually be read from the tension meter. The finest increments recommended earlier for reading a Wheelsmith Tensiometer are 0, 2.5, 5, and 7.5. Here are some examples.

Round anything from 68.8–71.2 to 70.0
Round anything from 71.3–73.7 to 72.5
Round anything from 73.8–76.2 to 75.0
Round anything from 76.3–78.7 to 77.5

The value determined in step #37 (page 17-15) is used in the **TRUING WHEELS WITH UNDAMAGED RIMS, SPOKES,**

AND NIPPLES worksheet. Transfer the value to step #86 (page 17-22) of the wheel-truing worksheet (if tension balancing the right side of wheel) or to step #104 (page 17-24) of the wheel-truing worksheet (if tension balancing the left side of wheel).

37. [ ] Round y to nearest reading ending in 0, 2.5, 5, or 7.5 and record here:
MINIMUM READING is: _____

TRUING WHEELS WITH BROKEN SPOKES OR DAMAGED NIPPLES

Most of repairing a wheel with a damaged nipple or broken spoke is the same as truing an undamaged wheel. The main differences are that it is necessary to determine the spoke length for a replacement spoke, and it is necessary to determine the spoke gauge for a replacement nipple. There can also be a little bit of a problem removing the damaged nipple.
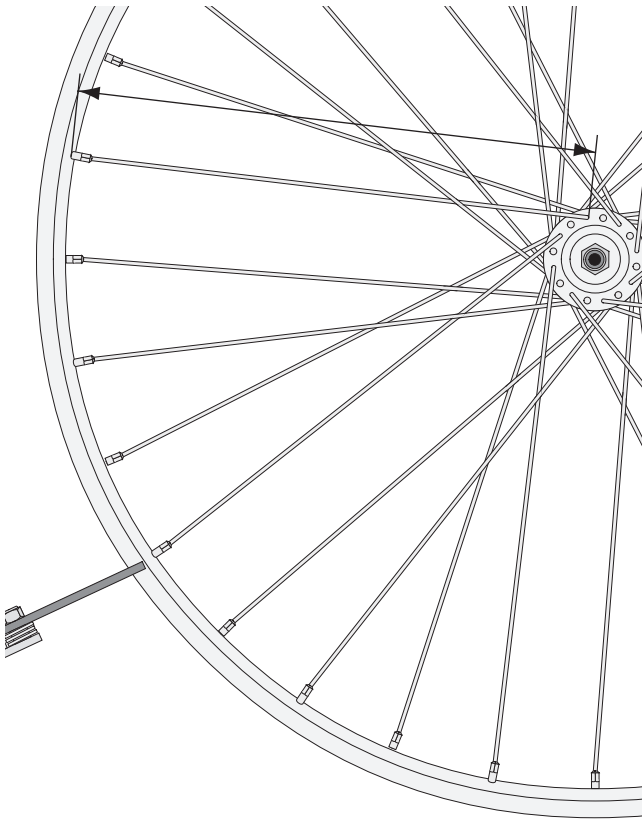
Preparations and inspections

1. [ ] Do steps 1–7 from TRUING WHEELS WITH UNDAMAGED RIMS, SPOKES OR NIPPLES procedure.
2. [ ] Remove rim strip from rim.
3. [ ] Rear wheels only, remove freehub cogs or freewheel.

Determining correct spoke length if replacing spoke

The spoke length can be calculated using various spoke-length programs or tables; when replacing a spoke, the simplest way to determine the correct length is to measure an existing spoke in the wheel. It will not be a precise measurement, but it will be adequate. Measure with a metric tape measure.

The proper way to measure a spoke that is installed in the wheel is to measure from the base of the nipple (where the nipple comes out of the rim) to edge of the spoke hole in the hub flange (the edge that is closest to the center of the wheel). These measuring points are shown in figure 17.23 (page 17-28). This is easiest to do by measuring a spoke that has its head on the inside of the hub flange; otherwise the spoke head covers the hole. On rear wheels, left and right spokes can be different lengths, so measure on the side of the wheel that needs the spoke replaced.

17.23 Measuring a spoke in the wheel.

4. [ ] Measure length of an installed spoke on same side of wheel as replacing spoke. Measure from inside face of rim to far edge of spoke hole in flange and write number here: _____mm

Determining the correct spoke gauge if replacing a nipple or spoke

In step #7 from the ***TRUING WHEELS WITH UNDAMAGED RIMS, SPOKES, AND NIPPLES*** procedure, the spoke gauge at the midpoint was measured so that the information could be used later to determine spoke tension. If the spoke is butted or aerodynamic, this measurement will not determine the right gauge for the nipple or spoke. It is best to double check, anyway. Use the midpoint measurement and the following end measurement to get a replacement spoke of the correct gauge as well.

5. Use calipers or spoke ruler to measure diameter of spoke just before it enters nipple. Compare measurement to following and check off one to indicate spoke gauge:
    [ ] 2.6mm– 12 gauge
    [ ] 2.3mm– 13 gauge
    [ ] 2.0mm– 14 gauge
    [ ] 1.8mm– 15 gauge

Removing and replacing a broken spoke

The easiest way to remove a broken spoke is to cut it an inch from the hub flange and then work the remainder out. Note which side of the flange the spoke head is on, then install the new spoke so that the spoke head ends up on the same side of the flange.

Look at the hub flange and see that the spokes alternate having their heads to the inside and to the outside of the flange.

If the new spoke is going to be a "head-out" spoke, after starting the new spoke through the hole in the correct direction, it may be necessary to flex it away from the hub when it gets to the other flange so that it will come out the opposite side of the wheel just beyond the crotch of two spokes in the opposite flange. If the spoke bows while doing this, it is not a problem.

A "head-in" spoke can just be laid out flat once it is pushed all the way into the flange.

Spokes will need to be bowed slightly to weave them past the other spokes and into their final position. Note that each spoke crosses several others in its path from the hub to the rim. Typically "head-in" spokes cross under the last spoke on the way to the rim and "head-out" spokes cross over the last spoke on the way to the rim. Just follow the pattern of the other spokes.

6. [ ] Remove broken spoke(s).
7. [ ] Put new spoke(s) in and thread on nipple(s) without tightening.

Removing and replacing a damaged nipple

Nipples are damaged from being over-tightened or from a misfit wrench being used. Sometimes they round off while being tightened and can still be turned the opposite way to loosen them. Sometimes they must be grasped with pliers or vise-grip pliers to break them loose. Try using a Park SW-10 nipple wrench instead. If the SW-10 slips, use a file to increase the flats on the nipple. Once the spoke is getting slack, it's all right to cut the spoke. Often the threads of the spoke are also damaged, and the spoke must be replaced.

8. [ ] Remove damaged nipple(s).
9. [ ] Thread on new nipple(s) without tightening.

Determining starting tension for the replaced spoke or spoke with replaced nipple

When a nipple is removed or a spoke is broken, the wheel can go wildly out of true, and it can look like a lot more than one spoke will be involved in making the correction. If the wheel was reasonably true to start with, before the spoke broke or damaged nipple was removed, then all it will take to get it back to the same degree of true is to adjust the new spoke/nipple. The key to doing this is to determine the tension average on the side of the wheel with the new spoke or nipple, then tighten the

new nipple/spoke to that tension. In the following steps, measure the tension of ten spokes on the side with the new spoke or nipple (excluding the new spoke or spoke with new nipple) and average the readings. Then tighten the new spoke or spoke with new nipple to the average reading. There is no need to use the tension-meter chart to convert readings to kilograms.

10. [ ] Measure tension on ten consecutive spokes on side with new spoke/nipple and record readings in following blanks.

_____ + _____ + _____ + _____ + _____

_____ + _____ + _____ + _____ + _____ = _____

11. [ ] Divide step 10 total by 10   ÷ 10
     Average reading is: = _____

12. [ ] Tighten new spoke/nipple to average reading calculated in step 11.

13. [ ] Replace freewheel/freehub cogs.

14. [ ] Do steps 8–127 from **TRUING WHEELS WITH UNDAMAGED RIMS, SPOKES, AND NIPPLES** procedure (page 17-11).

TRUING WHEELS WITH DAMAGED RIMS

The fundamental problem with repairing wheels with bends is that when metal bends, it elongates. Bending it back will not shrink it again. Bending it back just elongates it more. What this implies is that once a rim is bent, it can never be fully straightened. One big dent can be changed into a series of small, less obvious dips and bumps but cannot be eliminated. The more severe the bend is, the less likelihood of a successful outcome. The more over-correcting and re-correcting is done, the less likely the repair will ever make it to a successful point.

Rim bends can be broken down into three categories. These are dings in the outer perimeter of the rim, radial bends in the body of the rim, and lateral bends. Dings in the outer perimeter of the rim can be identified by two characteristics. There is a lack of any apparent radial error in the inner perimeter of the rim, and there is no evidence of loose spokes at the point of the radial error. Radial bends in the body of the rim can be identified by the fact that the very spokes that should be loosened to let out the dip are already looser than all the other spokes in the wheel. Lateral bends in the rim are identified by the fact that the very spokes that should be tightened to correct the rub are already tighter than any other spokes on their side of the wheel, or the very spokes that should be loosened to cor-

rect the rub are already looser than any other spokes on the same side of the wheel.

FIXING DINGS IN THE OUTER PERIMETER OF THE RIM

Dings limited to the outer perimeter of the rim are only a problem if they cause the rim sidewall to bulge out at the point of the ding, and this is unusual with aluminum rims. In any case, a tool is made to fix these, and they are relatively easy to fix as long as the dings are not severe.

1. [ ] Do steps 1–21 from **TRUING WHEELS WITH UNDAMAGED RIMS, SPOKES, AND NIPPLES** procedure.

The Bicycle Research RS1 Rim Saver is used to squeeze in rim-sidewall bulges. This tool is a pair of pliers with a wide jaw and a narrow jaw. The narrow jaw is placed against the sidewall bulge, and the wide jaw is placed against the other side of the rim. Be careful to squeeze the handles gently. Because no tool is made to spread the rim back out, it is better to under-correct and need to repeat the attempt than to over-correct and make the rim too narrow. To check whether the job is done, set a caliper to the rim width on an undamaged section of rim and try to slide the caliper past the damaged point. If it hangs up, continue to squeeze the rim narrower.

2. [ ] Use Bicycle Research RS1 to squeeze in any sidewall bulges detected during step 13 or step 16 of **TRUING WHEELS WITH UNDAMAGED RIMS, SPOKES, AND NIPPLES** procedure.

3. [ ] Do steps 21–127 from **TRUING WHEELS WITH UNDAMAGED RIMS, SPOKES, AND NIPPLES** procedure.

FIXING RADIAL BENDS IN THE BODY OF THE RIM

Radial bends in the body of the rim are detected during normal truing when the point is reached of correcting dips while truing radial. When correcting a dip (which is done by loosening spokes in the vicinity of the dip) and it is found that the spokes are already looser than any others in the wheel, a radial bend has been found.

To fix the problem, loosen the loose spokes even further, support the rim on wood blocks, apply impact to the inner perimeter of the rim, and then re-tighten the spokes. The reason that spokes must be loosened first is that the rim needs to be moved past the point at which it will end. Before the rim was damaged, the loose spokes at the point of damage were probably tight. If the repair is attempted without loosening the spokes, there will be resistance from the spokes before the rim is moved far enough.
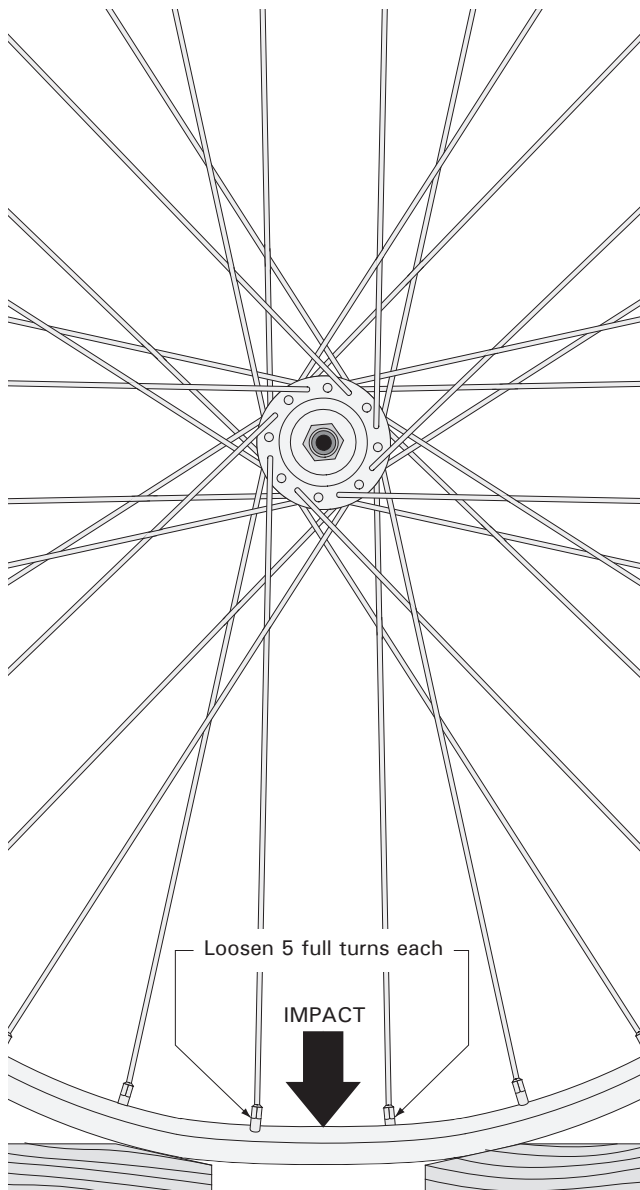
To set up the wheel for repair, first loosen the spokes in the affected area at least five full turns each. Support

the rim just outside the flattened area on two soft blocks of wood, such as furring strips (1×2 boards). The blocks of wood should be in line with the rim, not perpendicular. The repair will be done by striking the center of the bent section of rim with a rubber mallet.

After pushing out the rim, the spokes are tightened until the bump is eliminated. If they are at normal tension once the rim is round, the correction is done. If they are still loose, additional correction is needed. If they end up over-tight, the bend has been over-corrected. There is no good solution to this except to live with the rim having a bump and the spokes at that point being a little over-tight.

On paper this all sounds better than it actually works. It is difficult to hit the rim with the correct force, and the rim may bend in where it is supported on the blocks. A great deal of patience and skill with a rubber hammer is needed.

Loosen 5 full turns each

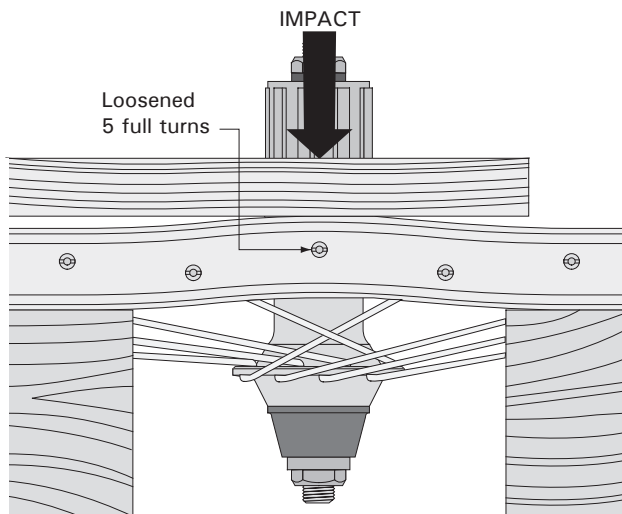IMPACT

17.24 Fixing a radial bend.

1. [ ] Do steps 1–36 from **TRUING WHEELS WITH UNDAMAGED RIMS, SPOKES, AND NIPPLES** procedure.
2. If at any time in step 33, spokes needing loosening seem too loose to start with, rim is bent.
   [ ] Loosen all spokes in affected area until nipples are almost off (at least 5 full turns).
   [ ] Place rim on wood blocks in line with rim, with blocks just past end of dip.
   [ ] Strike inner perimeter of rim near center of dip with rubber mallet.
   [ ] Put wheel in truing stand.
   [ ] Tighten spokes in affected area until bump is eliminated.
   [ ] Measure tension on spokes in affected area and compare to other spokes just outside affected area.
   [ ] If tensions are low, loosen spokes again and repeat procedure.
   [ ] If tensions are normal or high, continue from step 35 on **TRUING WHEELS WITH UNDAMAGED RIMS, SPOKES, AND NIPPLES** procedure.

FIXING LATERAL BENDS IN THE RIM

A lateral bend is identified when the spokes that need tightening to correct a rub are already over-tight or a spoke that needs loosening to correct a rub is already very loose.

There is no more difficult wheel repair then repairing a rim with a lateral bend. The rim needs to be unbent, and the only way to do it is to hit it on something (or with something) or stick the affected area in some sort of crack and apply leverage to the wheel. How much force to use can only be learned by trial and error. If putting the wheel in some crack and applying leverage, finding the right crack and figuring out how much rim to insert are a challenge. If using impact, it is recommended to put the rim on two wood blocks that support the rim just beyond the damaged area, with the side of the wheel that the rim bends to facing up. Next, cut a wood block that is just a little bit shorter than the damaged area and rest it on top of the rim on the damaged section. Strike the block on top of the rim with a hammer (see figure 17.25, page 17-31).

Like when repairing a radial bend, it is important to loosen the spokes on the side of the wheel where the damage is so that the rim can be pushed easily past the point at which it should end.

IMPACT

Loosened
5 full turns

17.25 Fixing a lateral bend.

1. [ ] Do steps 1–17 from **TRUING WHEELS WITH UNDAMAGED RIMS, SPOKES, AND NIPPLES** procedure.
2. [ ] When a lateral bend is detected while doing step 17, mark all spokes that are loose. (If none are obviously loose but on other side of wheel there are obviously tight spokes, mark all spokes on contact side of wheel from tight spokes that are within zone of tight spokes.)
3. [ ] Loosen nipples on all marked spokes exactly five *full* turns.
4. [ ] Remove rim from truing stand.
5. [ ] Use three foot-long two-by-fours to support the rim in following fashion. With the side of the wheel with loosened spokes facing up, put one two-by-four on its edge under rim 180° away from loosened spokes. Put other two-by-fours on their edges so that they are just on either side of range of loosened spokes and so that each two-by-four's full length supports rim.
6. [ ] Cut a short section of furring strip (one-by-two board) to be slightly shorter than affected area and place it on top of affected area.
7. [ ] Strike furring strip with hammer.
8. [ ] Put wheel in truing stand and check whether rub in affected area has switched to opposite side of wheel. (If not, repeat steps 4–8.)
9. [ ] Tighten spokes that were loosened exactly five *full* turns and check how spoke tension in affected area compares to adjacent spokes. If spokes that were loose are still loose, repeat steps 3–9.
10. [ ] Continue at step 19 from **TRUING WHEELS WITH UNDAMAGED RIMS, SPOKES, AND NIPPLES** procedure.

WHEEL TROUBLESHOOTING (table 17-4)

Cause	Solution
SYMPTOM: *A wheel fails to stay true for a reasonable time after truing but there is no evidence of a damaged rim.*	
Wheel was not stabilized.	Stabilize the true (see page 17-25, step 117).
Spoke tensions were too low.	Re-true wheel and set tension average closer to the maximum.
SYMPTOM: *Spokes lose tension rapidly.*	
Spokes were not tightened well.	Re-tighten spokes closer to maximum tension.
SYMPTOM: *Wheel will not hold tension even when it was tensioned high to begin with.*	
Rim and/or spoke choice is too light.	Rebuild with heavier components, or rebuild with Wheelsmith Spoke Prep or DT Spoke Freeze.
SYMPTOM: *Spokes are breaking at the bend or at the nipple.*	
Spokes are fatigued from age.	Rebuild or replace wheel.
Spokes are too light gauge (particularly if wheel is new and rider or usage can be described as heavy).	Rebuild wheel with heavier spokes.
Tensions are too low.	Rebuild wheel. (Low tension causes premature fatigue of all spokes.)
SYMPTOM: *Spokes are breaking in the middle.*	
Impact to spoke(s).	Replace broken spokes.
Low tension if at interlace.	Replace spoke, tighten spokes.
SYMPTOM: *Butted spokes are breaking at the transition of one gauge to the other.*	
Low-quality spokes.	Rebuild or replace wheel.
SYMPTOM: *More than one spoke is broken at the flange or at the nipples, or a variety of nipple and/or spoke types in the wheel indicate that spokes have broken in the past in addition to a single broken spoke that is being dealt with now.*	
Spokes are generally fatigued.	Rebuild or replace wheel.
SYMPTOM: *A spoke breaks when accelerating hard, hitting a bump, or while truing the wheel.*	
Spokes are generally fatigued.	Rebuild or replace wheel.
SYMPTOM: *Dimples or bulges are found in the sidewall of the rim.*	
Tire compresses fully when the wheel hits bumps.	Maintain full tire pressure and/or use a larger cross-section tire.
SYMPTOM: *Cracks are appearing in the rim sidewall; the rim sidewall is concave when it used to be flat or convex; the rim beads are wider apart than they were originally.*	
Rim sidewall is being worn thin by brake pads.	Replace rim immediately.
SYMPTOM: *Cracks are appearing at the nipple holes in the rim.*	
Spoke tension too high.	Replace rim immediately.
SYMPTOM: *While truing a lateral deviation, the spoke that needs tightening is too tight, or the spoke that needs loosening is too loose.*	
Rim has a lateral bend.	Bend rim back or replace rim.
SYMPTOM: *Rim has a lateral bend.*	
Excessive side loads have been applied to the rim through accident or abuse.	Avoid excessive side loads and/or use a stronger rim.
SYMPTOM: *While eliminating a radial dip (flat spot), the spokes that need to be loosened are too loose already.*	
Rim has a radial bend.	Bend rim back or replace rim.

Continued

WHEEL TROUBLESHOOTING (table 17-4 continued)

Cause	Solution
SYMPTOM: *Rim has a radial bend (flat spot).*	
Impact to wheel.	Maintain correct tire pressure and avoid road hazards, or use larger cross-section of tire.
Rim is too light (particularly when bend occurs repeatedly and tire pressure has been maintained).	Use a heavier rim.
Spoke gauge is too heavy for a lightweight rim.	Use light spokes with light rims.
SYMPTOM: *Complete wheel collapse (hyperbolic parabola).*	
Over-tight spokes.	Repair if possible, avoid over-tightening spokes.
Excess lateral loads on wheel.	Repair if possible, avoid loading wheel from side if possible.
SYMPTOM: *Stripped nipple wrench flats.*	
Over-tight spokes.	Avoid over-tightening.
Failure to lubricate nipple threads and heads.	Lubricate before truing.
Use of oversize nipple wrench.	Use correct size.
Attempted repair of damaged rim by spoke adjustment only.	Re-bend, then re-true if possible.
SYMPTOM: *Nipples frozen by corrosion.*	
Failure to lubricate or treat threads.	Lubricate or treat threads at time of building, at all times when re-truing, and once a month in climates where rust is a problem. Use stainless-steel spokes whenever possible.
SYMPTOM: *Bulges in the sidewall of the rim at each spoke or cracks or bulging at each spoke hole in the rim.*	
Spoke tension too high for rim strength.	Use less tension, but replace rim if cracked.
Inadequate support of the nipple at the rim.	Use nipple washers in non-eyeleted lightweight rims.
SYMPTOM: *Wheel will not install centered in frame or fork or bicycle pulls to one side when ridden.*	
Dish is incorrect.	Check and correct dish.
If dish is correct, frame or fork may be off-center.	Check and correct frame or fork alignment.
If dish is correct and frame or fork is aligned, dropouts may be unequal height.	File dropout slots to equalize height.
SYMPTOM: *A pinging or popping sound is heard continuously from the wheel (particularly rear) while riding.*	
Spoke tension is too low and slack spokes are rubbing on each other or on the spoke guard.	Tighten spokes.
SYMPTOM: *When the wheel is first ridden, popping and pinging sounds are emitted from the wheel, particularly when accelerating.*	
True was not stabilized, and spokes are unwinding when relieved of tension.	Stabilize the true (see page 17-25, step 117).