

Module 1.2B — Conduit Bending

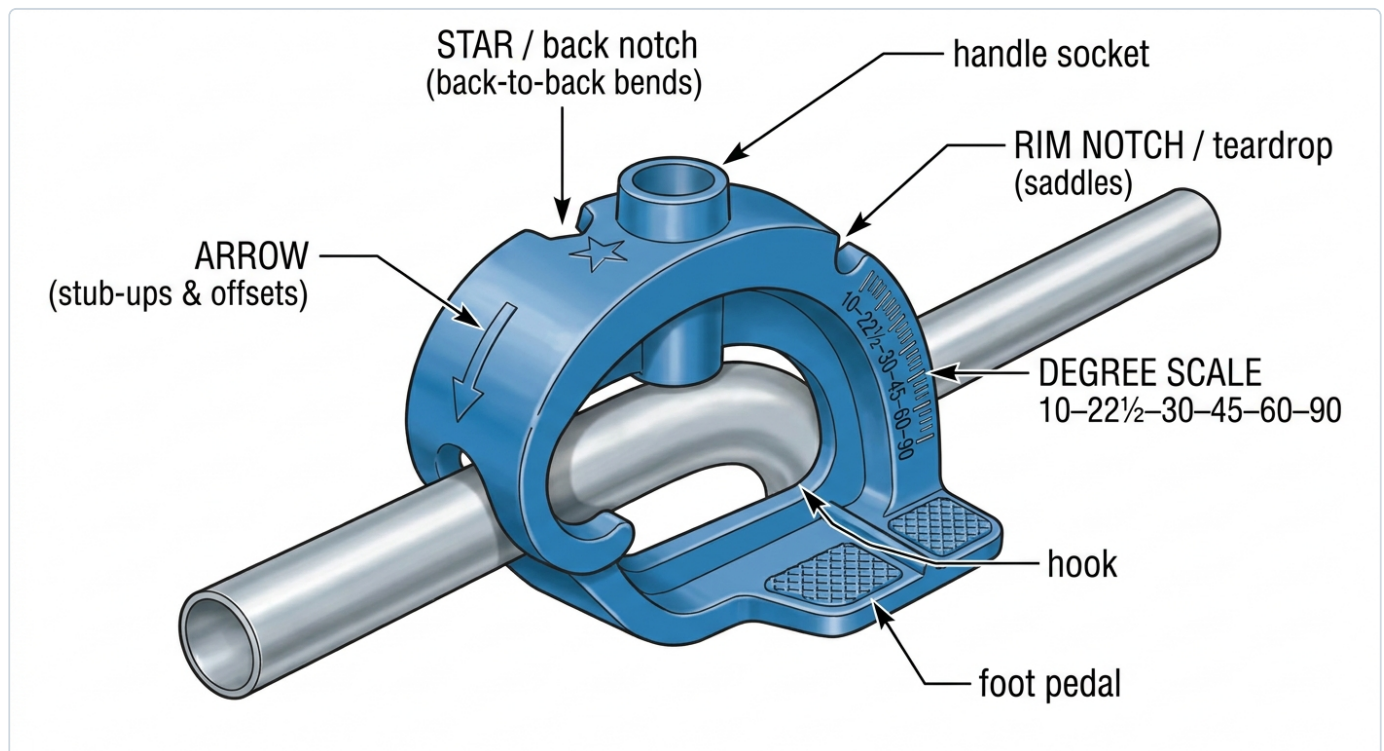
Masterclass

The skill that defines commercial work. The bender and its marks, the four core bends step by step, advanced and machine bends, and every number with a worked example.

Why a whole module on bending. Bending is the skill that separates a commercial electrician from a helper. Anyone can pull wire. Clean, accurate, repeatable bends are how your work gets judged on a job: by the foreman, the inspector, and the next electrician. This module covers the hand bender, the four core bends, the advanced bends, and the big mechanical, hydraulic, and electric benders, with every number you need and a worked example for each bend. The methods come from the published bender guides (IDEAL, Klein, Greenlee), Bill Bamford's guide hosted by Mike Holt, the IBEW Local 903 Bending Book, and The Master Bender Way.

Part A — The Tool: Your Bender Has Four Marks for a Reason

A hand bender works like four different tools, depending on which cast mark you line up. Learn the marks cold. Confusing them is the number-one beginner mistake.



The hand bender. Each cast mark is for a specific bend — using the wrong one is how you make scrap.

Mark	What it does	Used for
Arrow	Main alignment mark at the start of the bend	90° stub-ups, offsets, the outer marks of a saddle
Star	"Indicates the back of a 90° bend" (IDEAL), so no deduct math	Back-to-back bends
Rim notch / teardrop	Marks the center of the bender shoe. Klein also casts 30°/45°/60° notches	Center bend of a three-point saddle
Degree scale	Reads the angle as you bend: 10, 22½, 30, 45, 60. There is no 90° mark. Judge 90 with a level	Stopping at the exact angle on every bend

Matching the bender head to the pipe

One head bends two kinds of pipe. A **¾-inch EMT head bends ½-inch rigid**, a 1-inch EMT head bends ¾-inch rigid, and a 1¼-inch EMT head bends 1-inch rigid. Never bend rigid in an aluminum head; it will crack the head.

Step by step: a floor bend

1. Work on flat, hard ground. Lay the pipe on the floor with the hook toward the free end.
2. Put the mark on the pipe at the bender mark you need (Part A table).
3. Pin the pipe with one foot. Put your other foot on the foot pedal.
4. Bend with **heavy foot pressure for the whole bend**. Klein says this is "critical to keep the EMT in the bender groove and to prevent kinked conduit." The handle is a guide. Your foot does the work.
5. Check the angle with a torpedo level. Go slightly past the angle, because the pipe springs back a little.

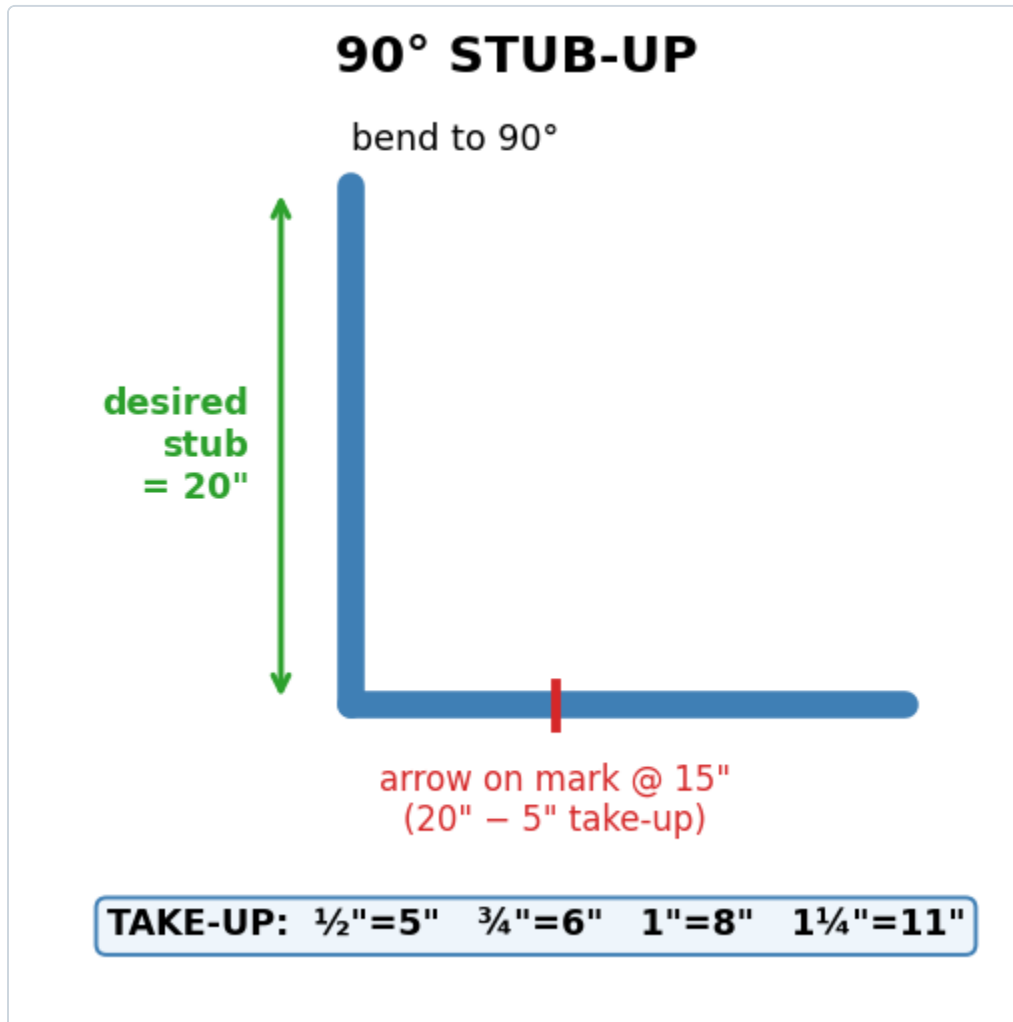
Step by step: an air bend (bender upside down)

1. Turn the bender over and set the end of the handle on the floor, braced by your foot.
2. Keep your body close. Push the pipe down with your hand and armpit, not just your arms.
3. ½ and ¾ inch EMT bend with the handle down. 1 and 1¼ inch is easier with the handle up, off the edge of a stair or a slab.
4. If you overbend, use a back pusher, or the reverse shoe on a hydraulic bender.

Safety while bending. Side-shield safety glasses (OSHA 1926.102). No damaged or sprung hand tools (OSHA 1926.301). Gloves, steel toes, hard hat. On machine benders: watch the pinch points, never stand in line with a hydraulic ram, the Greenlee 1800 weighs over 75 pounds so lift it with two people, never leave the ratchet handle up, run the 555 on a 120 V, 20 A GFCI-protected circuit, and unplug it before changing shoes.

Part B — The 90° Stub-Up

The L-shaped bend that brings conduit up out of the floor into a panel or up a wall. The whole bend hinges on one number: the **take-up** (also called deduct), which is how much pipe the bend itself uses up.



Stub-up: subtract the take-up from the desired height, put the arrow on that mark, bend to 90°.

Hand bender	½" EMT	¾" EMT or ½" rigid	1" EMT or ¾" rigid	1¼" EMT or 1" rigid
Take-up (deduct)	5"	6"	8"	11"

IDEAL and Klein bender guides; The Master Bender Way. Bigger pipe goes in a machine bender, and each machine has its own deducts (Part F).

Step by step

1. Pick the finished stub height, H. It is usually 12 to 36 inches.
2. Mark the pipe at H minus the take-up, measured from the end.
3. Mark all the way around the pipe so you can see the line from any side.

4. Hook toward the free end, **arrow on the mark**. The bend forms on the far side of the mark from the end you measured. Put the pipe in backward and a 26½-inch stub comes out instead of 21½.
5. Foot pressure, bend to 90°, check with a level, overbend slightly.
6. Cut the long leg to length after bending, then ream it. NEC 2026 358.28(A): "All cut ends of EMT shall be reamed or otherwise finished to remove rough edges."

Which way to measure (from The Master Bender Way)

- **Running toward a wall and turning up:** measure from the last coupling to the wall, and put the **star** on that mark. The back of the bend lands on the wall.
- **Coming down a wall from a box:** measure from the box to the floor, add the take-up toward the box, and use the **arrow**. Make the box offset first.
- **Worked example 1.** A 14-inch stub in ¾-inch EMT: $14 - 6 =$ mark at **8 inches**, arrow on the mark.
- **Worked example 2.** A 24-inch stub in 1-inch rigid on a Greenlee 1800: $24 - 11 =$ mark at **13 inches**, lined up with the front edge of the hook.
- **Worked example 3.** A 30-inch stub in 2-inch rigid on a Greenlee 880 hydraulic: $30 - 3\frac{1}{4} =$ **26¾ inches**, lined up with the center of the shoe. The ram travels 7¼ inches for a 90.
- **Unknown bender:** bend a scrap piece with its end flush at the arrow, then measure from the end to the floor. The difference from your bend height is that bender's take-up.

Part C — Back-to-Back (the "U")

Two 90s facing each other: up one wall, across, and down another, or to fit between two surfaces. The trick is the **star** mark.

BACK-TO-BACK 90s



2nd bend: put the
STAR on the mark —
no deduct needed

back-to-back distance (measured back of bend to back of bend)

Back-to-back: first 90 is a normal stub. For the second, put the STAR on the mark — no deduct.

Step by step

1. Bend the first 90 as a normal stub (Part B).
2. Measure from the **back** of the first bend to where the back of the second bend must be. Or set the stick in place and mark where it needs to turn.
3. Put the **star** on that mark, hook facing the free end, and bend toward the end you measured.
4. Keep the first leg flat and pointing straight up. Klein: it is "very important to keep the first 90° bend in the same plane."
5. Sight down the pipe. If the two legs are not in one plane, you have a dog-leg (a twist).

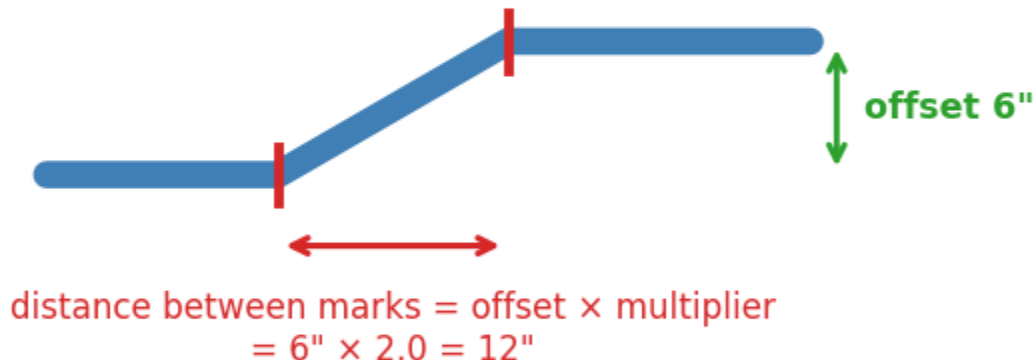
Short U with no room between the legs for the bender: subtract the take-up from your measurement, use the **arrow**, and bend away from the first 90. The first bend swings up toward you as you bend.

- **Worked example 4.** A 62-inch U in ½-inch EMT: mark 62 inches from the back of bend 1, star on the mark.
- **Worked example 5.** A 36-inch U with no room: $36 - 5 = 31$ inches, arrow on the mark, bend away.

Part D — The Offset

Two equal bends in opposite directions that step the conduit from one level to another, to clear an obstruction or rise into a box knockout. Two numbers govern it: the **multiplier** (distance between the two marks) and the **shrink** (length the run loses because it now travels at an angle).

OFFSET BEND (30° shown)



MULTIPLIER	10°$\times$6.0	22½°$\times$2.6	30°$\times$2.0	45°$\times$1.4	60°$\times$1.2
SHRINK/in:	10°=1/16"	22½°=3/16"	30°=¼"	45°=3/8"	60°=½"

Offset: distance between marks = offset height $\times$ multiplier. Add the shrink so it lands in the right place.

Bend angle	Multiplier ($\times$ height = distance between marks)	Shrink per inch of offset	Note
10°	6.0	1/16"	Box offsets (shallow)
22½°	2.6	3/16"	Low-profile
30°	2.0	¼"	Field default: easy math
45°	1.4	3/8"	Tight clearances
60°	1.2	½"	Steep or deep offsets

The multipliers are the cosecant of the angle, rounded the way they are cast on benders. A 15° bend uses 3.86. At 30°, the marks are 2 × the offset apart and the shrink is ¼ × the offset.

Step by step: an offset toward an obstruction

1. Measure the offset height, h , and the distance, D , from the end of the pipe (or the last coupling) to the obstruction.
 2. Mark 1, the one nearest the obstruction, at **$D + (h \times \text{shrink per inch})$** . IDEAL: "Ignore the shrink when working away from the obstruction, but be sure to consider it when working into it."
 3. Mark 2 at **mark 1 – ($h \times \text{multiplier}$)**, back toward the end. Mark both all the way around.
 4. Arrow on mark 1. Bend down into the surface you need to lift off of. Check the angle; bend 2 copies bend 1, so get it right.
 5. Leave the bender on the pipe with the handle on the floor. Slide it to mark 2, roll the pipe exactly 180°, arrow on mark 2, and air-bend the same angle.
 6. Sight down the pipe for a dog-leg before you take it out of the bender.
- **Worked example 6.** A 6-inch offset, 36 inches from the end, at 30°. Shrink = $6 \times \frac{1}{4} = 1\frac{1}{2}$ inches, so mark 1 is at **37½ inches**. Marks are $6 \times 2 = 12$ inches apart, so mark 2 is at **25½ inches**.
 - **Worked example 7.** A 6-inch offset, 20 inches to the obstacle, at 45°. Shrink = $6 \times \frac{3}{8} = 2.25$ inches, so mark 1 is at **22¼ inches**. Marks are $6 \times 1.4 = 8.4$ inches apart.
 - **Worked example 8.** You have exactly 15 inches to make a 4-inch offset. $\tan \theta = 4 \div 15$, which is 15°, so use the 3.86 multiplier.
 - **Worked example 9, ram travel.** A 3¼-inch offset at 20° in ¾-inch rigid on a hydraulic: $3.75 \times 2.92 = 10\text{-}15/16$ inches between marks. The ram travels 7¼ inches for 90°, so for 20° it travels $7\frac{1}{4} \div 90 \times 20 = 1\frac{5}{8}$ inches.

Box offset. The small ½ to ¾ inch step that lifts conduit off the wall into a box knockout. It is two shallow 10° bends close together. Most electricians do it by eye, and the same multiplier math applies.

Parallel offsets (several pipes stepping together)

To keep a rack of pipes evenly spaced through an offset, move each pipe's marks farther along than the last by **center-to-center spacing × tan(half the bend angle)**.

Worked example 10. Pipes 2 inches center to center, 30° offset: $2 \times \tan 15^\circ = 2 \times 0.2679 =$ about **9/16 inch** farther along for each pipe.

Rolling offset (up and over at the same time)

When the pipe must move up and sideways at once, find the **true offset**, which is the diagonal: $\sqrt{(\text{rise}^2 + \text{roll}^2)}$. Then bend a plain offset of that height.

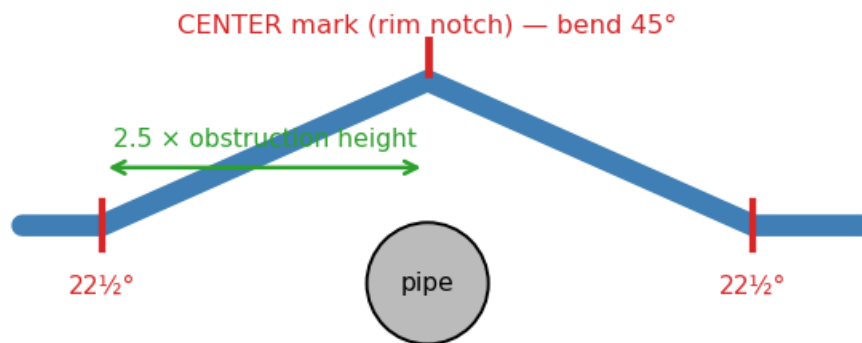
Rise	Roll	True offset
4"	3"	5"
5"	4"	6 $\frac{3}{8}$ "
5 $\frac{1}{2}$ "	5 $\frac{1}{2}$ "	7 $\frac{3}{4}$ "

For the 4 and 3 case at 30°, the marks are $5 \times 2.0 = \mathbf{10 \text{ inches}}$ apart.

Part E — The Three-Point Saddle

Jumps the conduit over a round obstruction such as a pipe or another conduit and back down. It is a center bend plus two outer bends at half the center angle.

THREE-POINT SADDLE (45°/22½°)



45°/22½° saddle: outer marks = 2.5 × height each side. 60°/30° = 2.0 × height (tighter).

Three-point saddle: rim notch on the center mark (45°), outer marks 2.5× the obstruction height each side (22½°).

Obstruction height	45°/22½°: move center mark ahead	outer marks each side	60°/30°: move center ahead	outer marks each side
1"	3/16"	2½"	¼"	2"
2"	3/8"	5"	½"	4"
3"	9/16"	7½"	¾"	6"
4"	¾"	10"	1"	8"
each extra inch	add 3/16"	add 2½"	add ¼"	add 2"

The "move ahead" column is the shrink. Dan Harmon's bending notes put it plainly: "most electricians forget about or ignore this shrinkage," and then "the center of their bend is not centered over the obstruction."

Step by step (45°/22½°, the common one)

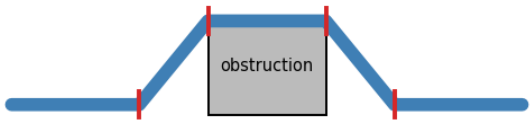
1. Measure from the end of the pipe to the **center** of the obstruction.
2. Center mark = that distance + the shift from the table. Outer marks = center mark plus and minus the spacing from the table. Mark all three around the pipe.
3. Put the **rim notch** on the center mark and bend **45°** down.
4. Don't take the bender off. Slide to the first outer mark, roll the pipe 180°, put the **arrow** on the mark, and air-bend **22½°**.
5. Take the pipe out, turn it end for end, and put the arrow on the second outer mark facing the center bend. The Master Bender Way: "This is important." Bend 22½°.
6. IDEAL: "Be sure to line up all bends to be in the same plane." Sight it.

A tighter **60°/30°** saddle uses **2.0 ×** the height for the outer marks and hugs the obstruction closer.

- **Worked example 11.** A 3-inch pipe 48 inches from the coupling, 45°/22½°: center mark at **48-9/16 inches**, outer marks at **41-1/16** and **56-1/16 inches**.
- **Worked example 12.** A 4-inch obstruction 41½ inches away, 60°/30°: center at **42½ inches**, outers at **34½** and **50½ inches**.

Part F — Advanced Bends

FOUR-POINT SADDLE



= two offsets back-to-back
(four equal bends)

ROLLING OFFSET

Offset that moves in TWO directions at once (up + over). Use the true offset (hypotenuse):

true offset = $\sqrt{(\text{rise}^2 + \text{roll}^2)}$
distance between bends = true offset × multiplier

Example: 4" up + 3" over → true = 5" →
at 30°: marks 5 × 2.0 = 10" apart.

Four-point saddle (two offsets back-to-back) and the rolling offset (offset that moves in two directions at once).

Four-point saddle (square or wide obstructions)

Two offsets back to back, four equal bends. Mark all four before you bend.

1. Mark 1 = distance to the front of the obstruction + shrink.
2. Mark 2 = mark 1 – the distance between bends (height × multiplier).
3. Mark 3 = mark 1 + the width of the obstruction.
4. Mark 4 = mark 3 + the distance between bends.

5. All bends use the arrow, pointing toward the obstruction. Bend 1 down, roll 180° for bend 2, turn the pipe end for end for bend 3, roll 180° for bend 4.

Worked example 13. An obstruction 2 inches high, 30 inches wide, 16 inches away, at 30°. Shrink = $\frac{1}{2}$ inch, between bends = 4 inches. Marks at **16½, 12½, 46½, and 50½ inches**.

Gain, and cutting the pipe to length before you bend

A 90° bend does not use as much pipe as its two legs add up to, because the pipe cuts the corner on an arc. That difference is the **gain**. The Master Bender Way's rule: "Always subtract gain but add shrink." To cut a piece to length before bending (useful on rigid, because you thread it first):

Length = all straight dimensions + each offset's shrink – each 90°'s gain + $\frac{1}{2}$ " of thread at each box end

Gain for a 90	$\frac{1}{2}$ "	$\frac{3}{4}$ "	1"	1½"
Rigid	2⅝"	3¼"	4"	5⅝"
EMT	2½"	3"	3-15/16"	—

Worked example 14. A 1-inch rigid piece with 92 inches of straight dimensions, $\frac{1}{2}$ inch of thread at each end, one 90, and 1 inch of offset shrink: $92 + \frac{1}{2} + \frac{1}{2} - 2\frac{5}{8} + 1 = \mathbf{91\frac{3}{8} \text{ inches}}$. To check gain on your bender: bend a 36-inch scrap with the end flush at the shoe and measure both legs. Legs of $7\frac{3}{4}$ and $31\frac{1}{2}$ inches add to $39\frac{1}{4}$, so the gain is $3\frac{1}{4}$ inches.

Concentric bends (a rack of pipes turning a corner)

Each pipe farther out gets a larger radius so the spacing stays even. Outer radius = inner radius + the center-to-center spacing. Match the radii to the largest pipe in the rack, not to the bender.

Worked example 16. Four 2-inch rigid conduits with 2-inch gaps, inner radius 20 inches. Center-to-center is $4\frac{3}{8}$ inches, so the radii are **20, 24⅜, 28¾, and 33⅜ inches**. Developed length of a 90 = $1.57 \times \text{radius}$: $31\frac{3}{8}$, $38\frac{1}{4}$, $45\frac{1}{8}$, and 52 inches. Split into 17 spaces each, the shot spacing is about $1\text{-}13/16$, $2\frac{1}{4}$, $2\frac{5}{8}$, and $3\text{-}1/16$ inches, with 18 marks at 5° each.

Segment bends on a hydraulic bender

A big sweep is many small bends ("shots"). Developed length (DL) = $0.01744 \times \text{degrees} \times \text{radius}$, which is $1.57 \times \text{radius}$ for a 90.

1. Figure the developed length.
2. Pick the number of spaces. The IBEW 903 Bending Book rule: keep spaces 3 inches or less. DL of 18 inches or less, 8 spaces at 10°. 19 to 36 inches, 17 spaces at 5°. Over 36 inches, 29 spaces at 3°.
3. Find the center of the bend on the pipe, then lay out the shot marks evenly on each side.

4. Advance the ram the same small amount for each shot.

Worked example 17 (Greenlee 880 manual). 2-inch rigid, 60-inch stub, 46-inch radius. $DL = 1.57 \times 46 = \mathbf{72.2 \text{ inches}}$. Center mark = $60 - 46 - 1.18 + 36.1 = \mathbf{48.92 \text{ inches}}$. Fifteen shots, 4-13/16 inches apart. Ram travel per shot = $6.2 \div 15 = \mathbf{0.41 \text{ inch}}$.

Machine benders, step by step

Bender	½"	¾"	1"	1¼"	1½"	2"	Line the mark up with
Greenlee 1800 (rigid/IMC)	5½"	8½"	11"	—	—	—	front edge of hook
Greenlee 880 hydraulic (rigid)	1-5/16"	1½"	1⅞"	2⅜"	2¾"	3¼"	center of shoe
Greenlee 555 electric (EMT)	7"	8⅞"	10¾"	13⅞"	13⅞"	15⅞"	front of hook

Deducts for a 90 from the Greenlee instruction manuals. Minimum stub: 1800 ½" = 6½"; 880 ½" = 9¼", 2" = 17¼"; 555 = deduct + 2". A ½-inch EMT 90 on the 555 deducts 7 inches, not the 5 inches a hand bender uses. Never use one bender's numbers on another.

Greenlee 1800 mechanical (ratchet) bender:

1. Set it on a flat floor, never on a slope. Use a 5-foot length of 1-inch rigid as the handle.
2. Raise the handle all the way, turn the shoe fully counterclockwise, and lower the handle.
3. Lay the pipe over the roller into the groove. Line your mark up with the front edge of the hook.
4. Lift the handle one click, push it down, and repeat. The angle indicator does not account for springback.
5. Raise the handle, return the shoe, remove the pipe, and leave the handle **down**.

Greenlee 880 hydraulic bender:

1. Pin the ram between the frame halves. Mount the shoe and the pipe supports in the holes for that pipe size.
2. Connect the hose couplers hand-tight to the 10,000 psi pump.
3. Zero the ram-travel scale. Line your mark up with the **center of the shoe**.
4. Pump to the ram travel for your angle from the manual's table (for ½ inch: 1⅝ inches for 10° up to 4⅜ inches for 90°; for 2 inch: 2 inches up to 7¼ inches).

Greenlee 555 electric bender:

1. Mount the shoe on the sprocket shaft and pin the support to the leg. Plug into a GFCI-protected 120 V, 20 A circuit.
2. Bump BEND or UNLOAD to get to 5 to 10° before 0°.
3. Line the mark up with the front edge of the hook.
4. For 1½ to 2 inch EMT or IMC, put your foot on the loading pedal and hold BEND until the roller support hits the stop.

5. Release just before your angle and bump BEND to finish. The scale reads about 95 for a finished 90 in ½-inch EMT, because of springback.
6. Press UNLOAD and twist the pipe off the hook. Side marking on the pipe means too much squeeze. An oval or wrinkled bend means too little.

Two rules you can never break (NEC 2026).

(1) **358.24(B)**: "The total degrees of bends in a tubing run shall not exceed 360 degrees between pull points." The same rule is 344.24(B) for rigid, 342.24(B) for IMC, 352.24(B) for PVC. (In 2023 this was 358.26; that number does not exist in the 2026 code.) Every offset counts as 2 × its angle. Every saddle counts as the center plus both outers. Keep a running total or you will need a pull box nobody planned.

(2) **358.24(A)**: "Bends shall be made so that the tubing is not damaged and the internal diameter of the tubing is not effectively reduced. The radius of the curve of any field bend to the centerline of the tubing shall not be less than shown in Chapter 9 Table 2." A flattened or kinked pipe jams the wire pull and shreds insulation.

Trade size	½	¾	1	1¼	1½	2	2½	3	3½	4	5	6
Min. radius, one-shot or full-shoe bender (in.)	4	4½	5¾	7¼	8¼	9½	10½	13	15	16	24	30

NEC 2026 Chapter 9, Table 2. The Greenlee 880 shoe radii match this row. The Greenlee 1800's ½-inch shoe is only a 2⅝-inch radius, so Greenlee says to bend ½-inch pipe in the ¾-inch position to get a radius over 4 inches.

Worked example 18, the 360° budget. Two 90s (180°) + a 30° offset (60°) + a 45°/22½° saddle (90°) = 330°. Add a 10°/10° box offset: 350°. One more 15° kick would make it 365°, so you put in a pull box first.

Common mistakes and the fix

Mistake	Fix
Wrong mark	Star only for back-to-back. Rim notch only for a saddle center. Arrow for everything else.
Dog-leg (twisted bends)	Mark all the way around, level bend 1, sight after every roll. If it's already bent, cut, ream, couple, and rotate.
Kinks	More foot pressure. Right-size head. Never use a hickey on EMT. On the 555, more squeeze.
Offset lands short	You forgot the shrink working toward the obstruction.
Saddle off-center	You forgot to move the center mark ahead.
Wrong deduct	Hand bender, 555, and 880 use different numbers. Check the bender in your hands.
PVC in a hand bender	Only small kicks. Bend it about twice as far; it springs back half. Real PVC bends need a heater.

Inspection checklist for every bent piece

- Radius at or above Chapter 9 Table 2. No flat spots, no kinks.
- No more than 360° of bends in the pull section.
- Every cut end reamed.
- Legs in one plane when checked with a straightedge or level.
- Dimensions within 1/16 inch of the layout.
- Push a fish tape through before the pull to prove nothing is pinched.
- Strapped within 3 feet of each box and every 10 feet for EMT (NEC 2026 358.30(A)).

Pro habits (from the IBEW & Master Bender guides)

- **Over-bend slightly** for springback, then check with a level or angle finder. EMT springs back the least.
- **Sight down the pipe** after any roll (offset, saddle, back-to-back) to catch dog-legs before you cut.
- **Pencil, not marker**, on exposed conduit. Marker bleeds through paint.
- **Practice on scrap** ("bones") for saddles and rolling offsets before the real stick.
- **Measure from the last coupling**, and know whether you are working toward or away from the obstruction.

Hands-On Progression (master in order)

1. Ten clean **90° stubs** in ½-inch EMT to a fixed height, until every one is identical. Then find the take-up of an unknown bender on scrap.
2. **Back-to-back** with the star mark, and a short U with the arrow. Sight for dog-legs.
3. **30° offsets** to a set height toward an obstruction, adding shrink. Then a **box offset** into a knockout.
4. **Three-point saddle** over a ¾-inch pipe (45°/22½°), with the center shift.
5. **Four-point saddle** and a **rolling offset** between two misaligned boxes.
6. Cut and thread a rigid piece to length from a layout before bending, using shrink and gain.
7. A **conduit rack**: several parallel offsets and matching concentric 90s on a machine bender.

Sources used in this module (public documents)

- IDEAL Industries, Bender Guide ND 1534-4. Klein Tools, Conduit Bender Guide.
- Bill Bamford, "Bending Conduit/Tubing Using Hand Benders," hosted at mikeholt.com.
- David L. Hensley, IBEW Local 903, Bending Book, Rev. II: lu903.com
- Lewis A. Hinkle, The Master Bender Way (2020): paweng.com
- Dan Harmon, "Formulas and Multipliers for Bending Conduit or Electrical Pipe."
- Greenlee instruction manuals: Site-Rite hand benders (IM1071), 1800 mechanical (IM 932), 880 hydraulic (IM 689), 555 electric (IM 1197).
- NFPA 70, National Electrical Code 2026: 110.12, 342.24, 344.24, 352.24, 358.24, 358.28, 358.30, Chapter 9 Tables 1-2.

- OSHA 29 CFR 1926.102 and 1926.301: [osha.gov](https://www.osha.gov)

Bonus masterclass module. Next in sequence: Module 1.3 — Conductors, Pulling & Terminations.