

Pipe materials and how they are joined

YES Electric • a plain-language course for new plumbing apprentices

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A plumber's first skill is telling pipe apart on sight. The second is knowing how each kind gets joined, because every material has its own glue, tool, or torch, and using the wrong one makes a joint that leaks or falls apart. This module goes material by material. For each one you learn what it looks like, where you will find it, how to join it, and what goes wrong with it.

The materials split the same way the plumbing does. Some carry pressurized clean water on the supply side. Some carry gravity drain water on the DWV side. A few show up on both.

The quick reference

Material	Where it is used	How you join it
PEX (flexible plastic, red/blue/white)	Supply lines in almost all new houses	Crimp rings, cinch clamps, or expansion rings (Uponor). Push-fit (SharkBite) for repairs.
Copper (type L in walls, type M some places, type K underground)	Supply lines in older houses, water heater connections, stub-outs	Solder with a torch ("sweating"), press fittings (ProPress), or compression.
CPVC (cream-colored plastic)	Supply lines in some tract houses, mostly 1990s to 2010s	Solvent cement, same idea as PVC but a different glue.
PVC (white, schedule 40)	Drains and vents, nearly all new houses	Purple primer, then solvent cement. Shove it in and give a quarter turn.
ABS (black plastic)	Drains and vents, mostly western states and older work	One-step black cement, no primer.
Cast iron	Drains in older houses, still used in some commercial for quiet	No-hub couplings with stainless bands, or old lead-and-oakum joints you only cut out.
Galvanized steel	Old supply lines, 1960s and earlier	Threaded. You see it when you tear it out. It rusts shut from the inside.
Brass	Valves, fittings, nipples, stop valves	Threaded with pipe dope or Teflon tape.

Material	Where it is used	How you join it
Flexible connectors	Water heater, supply tubes, gas appliances	Compression nuts or threaded unions.

Supply-side materials

PEX

PEX stands for cross-linked polyethylene. It is a flexible plastic tube that comes in coils or straight sticks. Red is for hot, blue is for cold, and white can be either. The colors are only a convenience for the plumber. The pipe inside is the same.



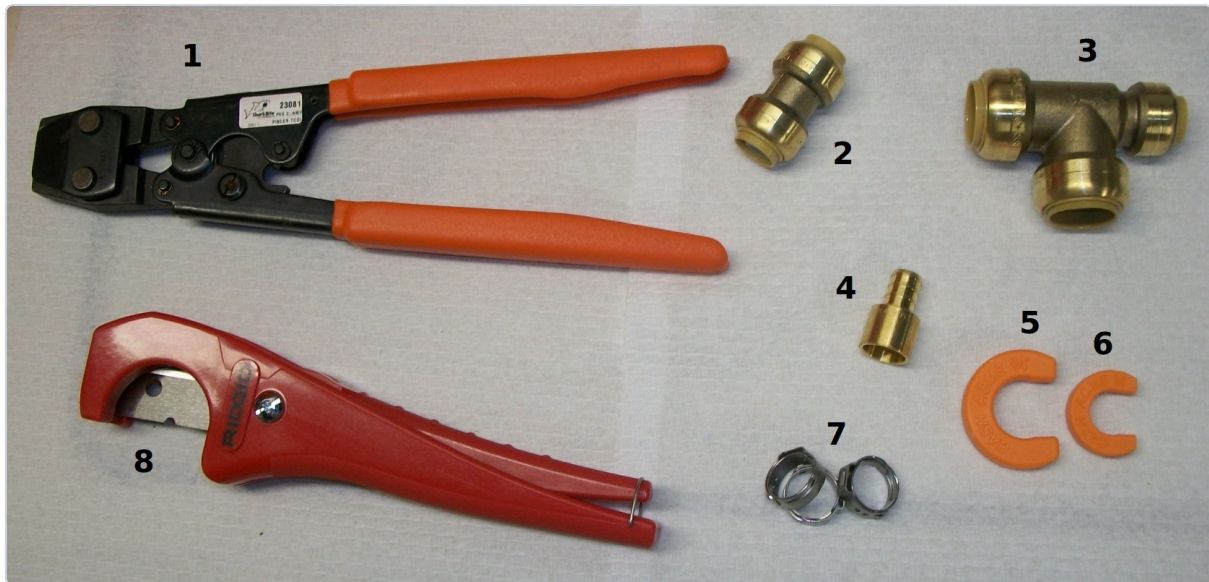
Red PEX carries hot water and blue PEX carries cold in a basement ceiling, with brass ball valves on each line. PEX is flexible plastic tubing that bends around corners without fittings.

Photo: PEX piping in basement ceiling.jpg by Tomwsulcer, CC0.

PEX took over new construction because it bends around corners without a fitting, it does not corrode, it survives a freeze better than copper, and a helper can learn to join it in an afternoon. It comes in 1/2, 3/4, and 1 inch for houses. It is sized by the inside of a copper pipe of the same name, so 1/2 inch PEX fits 1/2 inch copper fittings with an adapter.

There are three ways to join PEX and a plumber usually picks one system and sticks with it.

Crimp. A copper ring slides over the pipe. A brass or plastic fitting pushes inside the pipe. A crimp tool squeezes the ring down onto the pipe over the fitting. The ring must sit 1/8 to 1/4 inch back from the end of the pipe. After every crimp you check the ring with a go/no-go gauge, a little steel plate with slots in it. If the ring fits the "go" slot and not the "no-go" slot, the joint is right.



PEX connection kit: (1) cinch tool, (4) brass barbed fitting that slides inside the tubing, (7) stainless cinch rings that the tool squeezes tight over the tubing and barb, (8) PEX cutter. Items 2 and 3 are push-fit fittings.

Photo: PEX installation tools and fittings.jpg by Tomwsulcer, CC BY-SA 3.0.

Cinch clamp. Same idea as crimp, but the ring is a stainless steel band with a tab, and one cinch tool fits every pipe size. Easier in tight spots because the tool jaws are smaller.

Expansion. The expansion system, often called by the brand name Uponor, uses a different kind of PEX called PEX-A. A battery tool stretches the end of the pipe and a plastic ring. The fitting slides into the stretched pipe. Over the next few seconds the pipe shrinks back to its original size and grips the fitting. The tool costs more, but the joints have no metal ring to corrode and the fitting has the same inside diameter as the pipe, so it does not slow the water.



Hand expander tool for expansion-style PEX joints. The cone head goes into the end of the tubing and stretches it so a fitting can be pushed in before the tubing shrinks back tight.

Photo: Aufweitzange für Mehrschichtverbundrohre T2023.jpg by Deckenpappe2023, CC BY-SA 4.0.

Push-fit. Push-fit fittings, often called by the brand name SharkBite, have stainless steel teeth and a rubber O-ring inside. You push the pipe in and it locks. No tool, no ring, and it works on PEX, copper, and CPVC. They are the repair plumber's friend because they work on wet pipe where solder would fail. They cost about ten times what a crimp fitting costs, so they are not used to pipe a whole house.



Push-fit brass fittings (coupling and tee). Looking into the opening you can see the ring of steel teeth that grip the pipe and the plastic O-ring guide; the pipe is simply pushed in until it stops.

Photo: PEX compression connectors.jpg by Tomwsulcer, CC BY-SA 3.0.

PEX has rules. It cannot touch anything hotter than about 200 degrees, so it stays 6 inches or more away from a water heater flue and is not run into the heater itself without a short piece of copper first. It cannot sit in sunlight for long, because ultraviolet light makes it brittle. It needs a hanger every 32 inches on a horizontal run. Where it comes through a wall for a stop valve, it gets a stub-out bracket or a copper stub-out ear screwed to a block, so the pipe cannot wiggle when somebody turns the valve.

Copper

Copper was the standard supply pipe from the 1950s to the 2000s and it is still used for water heater connections, stub-outs, and anywhere a plumber wants a rigid pipe. It comes in three wall thicknesses, marked by the color of the print on the pipe.

Type	Print color	Wall	Where it goes
K	Green	Thickest	Underground service lines
L	Blue	Medium	Inside walls, the standard for houses
M	Red	Thinnest	Allowed in some places for inside use, cheaper



Copper water tube in a house with soldered fittings and a quarter-turn ball valve. The size and type of copper is printed along the tube (type L is blue print, M is red, K is green).

Photo: Copper Water Pipes and Water Line Shutoff.jpg by Tony Webster, CC BY 2.0.

Soldering. Also called sweating. You cut the pipe square with a tubing cutter, ream the burr out of the inside, and shine both the pipe end and the inside of the fitting with emery cloth or a wire brush until they are bright. You brush a thin coat of flux on both. You slide the fitting on and heat the fitting, not the pipe, with a torch until the flux bubbles. Then you touch lead-free solder to the joint on the side away from the flame. The heat pulls the solder into the gap all the way around. A good joint shows a thin silver ring at the edge of the fitting and nothing dripping. You wipe it with a damp rag. Water in the pipe ruins a solder joint, because the water keeps the copper from getting hot enough. Bread stuffed in the pipe to hold back drips is an old trick that still works.



Soldering a copper elbow: the torch flame heats the fitting while a roll of wire solder is touched to the joint. The open flux tin sits at lower right. The copper was cleaned and fluxed before heating.

Photo: Löt Brenner in der Anwendung.jpg by Quicksilver86, CC BY-SA 4.0.

Press. A press fitting has an O-ring inside. A battery tool with jaws squeezes the fitting down onto the pipe in a few seconds. No flame, no flux, and it works on wet pipe. The tool costs more than a used truck, so it belongs to the shop, not to the apprentice.



Press-fit copper elbow after pressing. The raised bead at each end of the fitting holds an O-ring; the press tool squeezes the bead onto the pipe so no solder or flame is needed.

Photo: Copper-press-fitting.JPG by Cschrp, CC BY-SA 3.0.

Compression. A brass nut and a brass ring called a ferrule slide onto the pipe. The nut tightens onto a fitting and squeezes the ferrule into the pipe. Stop valves under sinks are the most common compression joint. Compression works on copper and on CPVC with the right ferrule. It does not work well on PEX because the pipe is too soft.

Copper fails from the inside in houses with acidic water, which leaves pinhole leaks. It also splits when it freezes. Both show up on the repair list.

CPVC

CPVC is a cream or light yellow plastic pipe that was popular in tract houses from the 1990s into the 2010s because it was cheaper than copper and glued like PVC. It is sized like copper, so 1/2 inch CPVC fits 1/2 inch stop valves. It joins with its own orange or yellow solvent cement, not PVC cement. The glue melts the surface of both parts and they weld together as it dries.



CPVC pipe and tees. CPVC is cream colored and is rated for hot water; the white pipe on the left is regular PVC for comparison.

Photo: CPVC tees.jpg by Asadabbas, CC BY-SA 4.0.

CPVC gets brittle with age and with heat. Old CPVC cracks when you touch it, which makes repairs tricky. Most plumbers replacing a section of CPVC switch to PEX with a push-fit or a special transition fitting.

Galvanized steel

Galvanized pipe is steel coated with zinc. It was the supply pipe in houses built before about 1960. It joins with threaded fittings and pipe wrenches, two of them, one to hold and one to turn. The threads get coated with pipe dope or Teflon tape.



Section cut from an old steel pipe. Hard mineral scale has built up inside until only a small slot is left open for water.

Photo: Boiler Scale.JPG by 1e4cMET, CC BY-SA 3.0.

Galvanized rusts from the inside. A 50 year old 3/4 inch pipe may have an opening left the size of a pencil. Low pressure and brown water are the clues. An apprentice almost never installs galvanized water pipe. The job is cutting it out and replacing it with PEX. Threaded black steel, which is the same pipe without the zinc, is still used for gas lines, and that is where the threading skills still matter.

Brass

Brass is the metal for valves, stop valves, nipples, hose bibs, and most fittings that have to accept threads. It does not rust and it machines well. Brass fittings thread onto steel or onto other brass with pipe dope or tape, and they accept solder or compression on the copper side.

Drain-side materials

PVC

PVC is the white plastic pipe that makes up the drain, waste, and vent system in nearly every house built since the 1980s. For drains it is schedule 40, which refers to the wall thickness, and it comes in 1 1/2, 2, 3, and 4 inch for houses. Thin-wall PVC sold for sprinklers and the gray PVC sold for electrical conduit look similar and are not allowed for drains.



White Schedule 40 PVC pipe and fittings on a bench: a reducer, couplings, a union, and a can of all-purpose solvent cement.

Photo: Sticking the tees into the pvc.jpg by Asadabbas, CC BY-SA 4.0.

Joining PVC is a two-step glue job. Cut the pipe square, take the burr off the inside and the outside, and dry-fit the parts together. Mark the pipe and the fitting with a pencil line so you can line them back up. Pull apart. Wipe purple primer on the outside of the pipe end and the inside of the fitting. While the primer is still wet, brush on a layer of PVC cement in both places. Push the pipe into the fitting with a quarter turn to spread the glue and hold it for 30 seconds so it does not push back out. A bead of cement should show all the way around the joint. The cement sets in under a minute, so you work one joint at a time and you do not get a second try. Some inspectors require the purple primer because it proves the joint was primed. Clear primer exists for finished areas.



Cans of purple primer and clear PVC cement. The primer softens and cleans the plastic; the cement is applied on top of it and the parts are pushed together right away.

Photo: Water Ram Repair Primer and Cement.jpg by Jshin722, CC BY-SA 3.0.

PVC is cut with a handsaw, a reciprocating saw, or a ratchet cutter for the small sizes. It hangs every 4 feet on a horizontal run. It expands and shrinks with temperature more than metal, so long runs need a little room to move.

ABS

ABS is the black plastic drain pipe. It is common in the western United States and in houses from the 1970s and 1980s elsewhere. It joins with a one-step black cement, no primer. ABS and PVC cannot be glued to each other. Where the two meet, a rubber Fernco coupling or a special transition cement approved for that joint is used.

Cast iron

Cast iron was the drain pipe in houses built before about 1975. It is heavy and brittle. It is still used in some commercial buildings because it is quiet. Water rushing down a PVC stack behind a bedroom wall sounds like a waterfall. Cast iron is nearly silent.



Cast iron drain pipe under a floor, joined with rubber sleeve couplings held by stainless steel bands. A copper vent pipe ties in with the same kind of coupling.

Photo: Cast fe and cu dwv piping.jpg by Achim Hering, CC BY 3.0.

Old cast iron was joined with hubs. The small end of one pipe sat inside the bell end of the next, and the gap was packed with oakum rope and then poured full of molten lead. An apprentice never makes a lead joint. You cut them out. Modern cast iron is "no-hub" and joins with a neoprene sleeve and a stainless steel band clamp tightened with a torque wrench that clicks at 60 inch-pounds.

Cutting cast iron is a job of its own. A snap cutter wraps a chain of cutting wheels around the pipe and squeezes until the pipe cracks in a clean ring. A reciprocating saw with a carbide blade also works but is slow. Always support a cast iron stack above the cut, because the stack can drop when the joint below breaks.

Fernco couplings

A Fernco is a flexible rubber sleeve with a stainless band clamp at each end. It is the fitting that joins unlike things. Cast iron to PVC. ABS to PVC. Old 4 inch clay sewer to new 4 inch PVC. They come in every size and in step-down versions. For buried joints, a shielded version with a stainless steel sleeve around the rubber keeps the joint from sagging. A plain unshielded Fernco is not allowed underground in most codes.



Flexible rubber couplings with hose-clamp bands joining a copper pipe to cast iron. This is how two different pipe materials are connected without threads or solder.

Photo: Cast fe and cu dwv piping.jpg by Achim Hering, CC BY 3.0.

What the apprentice sees on a demo

When old plumbing comes out, the materials tell the age of the house. Galvanized supply and cast iron drains mean before 1960. Copper supply and cast iron drains mean 1960 to 1975. Copper supply and PVC or ABS drains mean 1975 to 1995. CPVC supply means a tract house from 1995 to 2010. PEX means new work or a repipe. Most old houses have two or three generations mixed together where someone did a bathroom and left the rest alone.

Copper and brass go to the scrap yard and pay for lunch. Cast iron scraps for a few cents a pound. Galvanized is worth almost nothing. Plastic goes in the dumpster.

Check yourself

1. What do the red, blue, and white colors on PEX mean, and does the pipe differ inside?
2. Name the three ways to join PEX and the one tool you use to check a crimp.
3. What do the green, blue, and red print colors on copper tell you?
4. Why does a wet pipe ruin a solder joint?
5. Why is PVC glued in two steps and what is the purple can for?
6. How did old cast iron joints get made, and how are new ones made?
7. Can ABS be glued to PVC? What do you use instead?
8. A house has galvanized supply pipe and cast iron drains. About how old is it?

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