



Brazing, Swaging, and Mechanical Joining

MODULE C16

CORE SYSTEMS

PREREQ F2

A tech replaces a failed compressor in June. Clean work, good vacuum, system runs. Three weeks later the same house is warm again, and this time the TXV is starved and the new filter drier is plugged with black flakes. Nobody can see those flakes form, because they form on the inside of the copper while the torch is lit. The tech brazed without flowing nitrogen, the brazing heat burned the oxygen inside the pipe into black copper oxide scale, and the system spent three weeks washing that scale into the two tightest spots in the circuit. The callback was decided before the first joint cooled. This module is about making joints that hold pressure for twenty years, and about the invisible rule that separates a clean repair from a guaranteed callback.

In F2 you met the tubing cutter, the deburring tool, the swage and flare tools, the torque wrench, and the nitrogen regulator with its flow meter. This module puts fire and force behind all of them. You will learn to run an oxy-acetylene torch safely, braze copper with nitrogen flowing, tell brazing apart from soldering, swage a joint, make a flare that passes a torque spec, know where press fittings belong, and handle the new rules that A2L refrigerants put on every hot-work decision.

Short Version

There are four ways to join refrigerant lines: braze it, swage-and-braze it, flare it, or press it. Brazing uses an oxy-acetylene torch and a filler alloy that melts above 1200 F and gets pulled into the joint by capillary action. The torch is the most dangerous tool on the truck, so tank handling, flashback arrestors, and the lighting and shutdown sequence are non-negotiable habits. While any joint is being brazed, nitrogen must flow through the line at 2 to 5 SCFH, because brazing heat plus the oxygen in normal air creates cupric oxide scale inside the pipe, and that scale plugs TXV screens and filter driers weeks later. Copper-to-copper takes a 15 percent silver phosphorus-copper rod with no flux. Dissimilar metals take a high-silver rod with flux. Soft solder and silver-bearing solder melt far below brazing temperature and have no place on high-pressure refrigerant lines. Flares are the mini-split standard and live or die on deburring and torque values. Press fittings join lines with no flame at all, where the manufacturer and the inspector allow them. A2L refrigerants add one absolute rule: never put a flame on a system that held A2L refrigerant until it has been recovered, nitrogen purged, and verified gas-free with a detector, and even then you cut the line open instead of unsweating it.

Key Values

ITEM	VALUE	WHY IT MATTERS
Nitrogen purge flow while brazing	2 to 5 SCFH on a flow meter	Displaces oxygen inside the pipe so brazing heat cannot form cupric oxide scale. Flow, not pressure.

ITEM	VALUE	WHY IT MATTERS
Acetylene maximum working pressure	15 psig, never higher	Above 15 psig free acetylene becomes unstable and can decompose explosively, with no spark needed.
Acetylene cylinder valve opening	3/4 to 1 turn, wrench left in place	Lets you close it instantly in an emergency.
Brazing vs soldering dividing line	840 F filler melt temperature	The American Welding Society line. Above 840 F is brazing, below is soldering.
Soft solder (95/5 tin-antimony) melt	Roughly 450 F	Plumbing material. Never on high-pressure refrigerant lines.
Silver-bearing soft solder melt	Roughly 430 to 535 F	Still soldering, despite the word silver on the label. Not a refrigerant-line joint.
15 percent silver phosphor-copper rod (BCuP)	Melts around 1190 F, flows fully near 1475 F, working range roughly 1300 to 1500 F	The copper-to-copper standard. Phosphorus self-fluxes on copper.
High-silver rod (BAG, 45 to 56 percent silver)	Working range roughly 1145 to 1400 F, flux required	For copper to brass, copper to steel, and any dissimilar joint.
Copper melting point	1981 F	Your ceiling. A torch can reach it. Overheated copper sags, thins, and blows through.
Braze fit-up clearance	0.002 to 0.006 inch	Capillary action only works in a tight gap. Sloppy fit means a weak, leaky joint.
Swage insertion depth	Equal to the tube outside diameter	A 3/8 inch tube swages to accept 3/8 inch of insertion. Shallower joints leak.
Flare torque, 1/4 inch	Roughly 10 to 14 ft-lb (confirm against manufacturer table)	Under-torqued leaks now, over-torqued cracks and leaks later.
Flare torque, 3/8 inch	Roughly 24 to 31 ft-lb	Same rule, every size.
Flare torque, 1/2 inch	Roughly 36 to 45 ft-lb	Same rule.
Flare torque, 5/8 inch	Roughly 45 to 60 ft-lb	The big mini-split suction flare, the most common leak point when done by feel.
Hot work combustible clearance	35 feet, or shield what cannot move	The OSHA fire-prevention radius for welding and brazing.
Fire watch after hot work	30 minutes minimum	Smoldering ignition shows itself after the torch is packed up.
R-454B competent ignition source	Heat above 1290 F or an open flame	A brazing torch is both. This is why A2L hot work has its own protocol.

ITEM	VALUE	WHY IT MATTERS
R-454B lower flammability limit	11.25 percent by volume in air	The concentration that area monitoring is protecting you from ever reaching.

Field Checklist

Run this before the torch comes off the truck, every time.

- Cylinders secured upright on the cart or in the rack, caps on until regulators go on
- Regulator threads clean, no oil or grease anywhere near the oxygen side
- Regulator adjusting screws backed out before opening either cylinder valve
- Flashback arrestors installed and inspected, hoses free of cracks and burns
- Acetylene valve opened 3/4 to 1 turn, wrench left on the valve
- Oxygen valve opened fully, standing to the side of the regulator face
- Acetylene regulator set, never above 15 psig
- Work area cleared: combustibles moved 35 feet or shielded, extinguisher staged within reach
- Heat shield or wet rag protecting anything behind the joint
- Nitrogen connected, flowing 2 to 5 SCFH through the line, exit path open
- Joint cleaned bright with abrasive pad, fit-up checked, tube fully seated
- Correct rod for the metals: phos-copper for copper-to-copper, high-silver plus flux for dissimilar
- If the system ever held A2L refrigerant: recovered, purged, verified gas-free with the A2L detector, monitor running
- After brazing: shutdown sequence completed, valves closed, lines bled, 30 minute fire watch
- PPE per F1: shaded brazing glasses, gloves, no synthetic sleeves near the flame

IB STANDARD

Nitrogen flows on every braze. Every joint, every job, every time, no exceptions. There is no joint small enough, no schedule tight enough, and no attic hot enough to justify brazing dry. A joint brazed without flowing nitrogen is a defect even if it holds pressure, because the scale it created is already in the system. If the flow meter is broken or the tank is empty, the braze waits.

Full Breakdown

The four ways to join a line

F2 introduced the tools of copper joining as a preview. Here is the full map. Every refrigerant line connection on a residential system is made one of four ways.

A brazed joint is a socket joint, one tube inside a fitting or a swaged tube end, filled with a metal alloy melted above 1200 F. It is the strongest and most permanent joint, the default for line sets and component changes.

A swaged-and-brazed joint is the same thing without a coupling: a swage tool expands one tube end into its own socket, the mating tube slips in, and the joint gets brazed. One joint to leak instead of two.

A flare joint is mechanical. The tube end is shaped into a 45 degree cone that a flare nut clamps against a matching seat. No flame at all, fully serviceable, and the standard connection on every mini-split.

A press fitting is also mechanical: a fitting with internal O-rings is crimped permanently onto the tube by a powered press tool. No flame, fast, and increasingly common where open flame is a bad idea.

Two of these need a torch. So the torch comes first.

The oxy-acetylene rig: tanks and handling

An oxy-acetylene torch burns acetylene gas in pure oxygen, producing a flame around 5,600 F at the inner cone tip. That is nearly three times the melting point of copper, which is why it brazes quickly and why it deserves respect.

The oxygen cylinder is a tall, heavy bottle holding gas at up to about 2,200 psi. High-pressure physics from F1 applies: a cylinder that falls and snaps its valve becomes a rocket. Cylinders ride secured and upright, caps on whenever a regulator is not installed, chained or strapped on the cart and in the truck. One more rule unique to oxygen: no oil or grease ever touches an oxygen fitting, regulator, or valve. Pure oxygen makes petroleum products ignite violently. Wipe your hands before you touch the oxygen side.

The acetylene cylinder is different on the inside and the rules follow from it. Acetylene is unstable as a free gas under pressure, so the cylinder is packed with a porous filler soaked in liquid acetone, and the acetylene is dissolved in the acetone the way carbonation is dissolved in soda. This is why the acetylene cylinder always stays upright in use: laid on its side, liquid acetone can reach the valve and get drawn into your regulator and hose. If a cylinder has been horizontal in transit, stand it upright and let it settle before use. And the hardest rule in the trade's gas handling: acetylene is never used above 15 psig. Above that pressure, free acetylene can decompose all by itself, explosively, without a spark. Regulators have a red zone for a reason.

Opening sequence for the cylinders: back the regulator adjusting screws all the way out first, so the regulators open gently instead of slamming full cylinder pressure into the diaphragm. Stand to the side of the regulator face, not in front of it, when you crack the valve. The oxygen valve opens all the way, because it has a double seat that seals at full open. The acetylene valve opens 3/4 to 1 turn only, with the wrench left in place on the stem, so you can kill the gas in one second if anything goes wrong.

Regulators, hoses, and flashback arrestors

Each cylinder gets a regulator, the same idea as the nitrogen regulator from F2: two gauges, one reading cylinder contents, one reading delivery pressure, with an adjusting screw between them. Oxygen fittings are right-hand thread. Fuel gas fittings are left-hand thread with a notched nut, so the hoses physically cannot be swapped. Green hose is oxygen, red is acetylene.

A flashback arrestor is a small one-way safety device installed at the regulator outlet, the torch inlet, or both. Here is the failure it prevents: a flashback is the flame burning backward up the hose toward the cylinder,

usually after a backfire (the sharp pop when a flame goes out and reignites at the tip). A flashback that reaches a cylinder is a catastrophe. The arrestor contains a check valve and a flame barrier that stops the burn-back cold. Arrestors on both gas lines are an IB requirement, not an option, and they get inspected with the hoses: cracks, burns, soft spots, and oily residue all fail.

Lighting and shutdown: the sequence is the safety

Lighting a torch is a fixed sequence, the same every time, so it becomes muscle memory.

1. Set working pressures with the torch valves closed: acetylene per the tip chart and never above 15 psig, oxygen per the tip chart.
2. Open the torch acetylene valve about a quarter turn and light it immediately with a striker. Never a lighter, which puts a butane cylinder inside a ball of flame, and never another torch.
3. Feed acetylene until the flame stops smoking and just leaves the tip, then add oxygen with the torch oxygen valve.
4. Adjust to the flame you want (next section).

Shutdown is the reverse priority: close the torch acetylene valve first, which extinguishes the flame instantly and removes the fuel, then close the torch oxygen valve. When the work session ends, close both cylinder valves, open the torch valves one at a time to bleed each hose until both regulator gauges read zero, then back out the regulator adjusting screws. A bled rig has no pressurized gas sitting in the hoses while it bounces around the truck.

If you ever hear a sustained hissing or squealing with a flame burning inside the torch body, that is a flashback in progress: shut the torch oxygen valve immediately, then the acetylene, then the cylinders, and let everything cool before you even think about diagnosing it.

Flame types and tip selection

With the torch lit, the oxygen-to-acetylene ratio gives you three different flames, and only one of them belongs on a refrigerant line.

A carburizing flame has excess acetylene: a long, feathery inner cone with a visible acetylene feather around it. It is relatively cool and adds carbon to the work. A slightly carburizing flame has its uses on thin material, but a heavy one soots the joint.

A neutral flame burns the gases in balance: a crisp, well-defined inner cone with no feather. This is the brazing flame. Nearly all of your work happens here.

An oxidizing flame has excess oxygen: a short, hissing, pale inner cone. It is the hottest of the three and it actively burns the metal surface, creating oxides at the joint face while you work. Wrong for brazing. If the flame hisses and the cone has shrunk to a sharp point, back the oxygen off.

Tip size follows the work. Small tips for 1/4 and 3/8 inch lines, larger tips for 3/4 inch and up, and a multi-flame rosebud tip when you need to flood a large fitting with heat fast. An undersized tip is the beginner's trap: the joint never quite reaches temperature, the tech holds the flame on it for minutes, and the copper anneals, oxidizes, and the rod balls up instead of flowing. Match the tip to the tubing and the joint comes up to temperature in seconds, not minutes. Many techs also carry an air-acetylene torch (the turbo-swirl style) for

small lines; it runs on acetylene and entrained air, tops out cooler than oxy-acetylene, and is fine for 1/4 to 5/8 inch copper with phos-copper rod.

Hot work around structures

You are bringing a 5,600 F flame into someone's home. OSHA's fire prevention rule for welding and brazing is the 35-foot rule: move combustibles at least 35 feet from the work, and shield anything that cannot move. In residential service that translates to: pull back insulation around the joint, move stored boxes away from the work area in a garage, wet-rag or heat-shield the wall behind a lineset penetration, and stage a fire extinguisher within arm's reach before the striker clicks. Heat shields (woven silica blankets or paste) protect framing, wire insulation, and finished surfaces behind the joint, because the flame does not stop at the copper.

Then stay 30 minutes after the last flame. A fire watch is exactly what it sounds like: smoldering insulation, paper facing, or dust does not flame up while you are standing there with a torch; it flames up twenty minutes after you drive away. Brazing is the last hot thing you do before cleanup, and cleanup takes longer than 30 minutes anyway if you do it right.

PHOENIX FIELD NOTE

Desert landscaping is kindling. Decomposed granite does not burn, but the dried palm skirts, bougainvillea litter, mesquite duff, and bark mulch packed against a condenser pad in July absolutely do, and a single drop of glowing brazing alloy falling into it starts a fire that the afternoon wind feeds. Rake the area around an outdoor braze down to bare rock before lighting, and keep the extinguisher staged outdoors with you. Attics are the other Phoenix hazard: 150 F attic air, blown-in cellulose insulation that ignites at low temperature, and truss lumber baked bone-dry for thirty years. For attic brazing, clear insulation a full arm's length around the joint, lay a heat blanket under and behind the work, never set a lit torch down on a joist, and take the fire watch seriously in the one environment where you least want to linger. If a joint can be relocated, flared, or pressed instead of brazed in deep attic insulation, that is the better engineering decision, not a shortcut.

The nitrogen purge rule

This is the most important section in the module.

Normal air is about 21 percent oxygen. When you heat copper above roughly 800 F with air inside it, the oxygen in that air reacts with the hot copper wall and forms cupric oxide: a brittle, black, flaky scale coating the inside of the tube. You cannot see it form, because it forms on the inside while you watch the outside. The braze looks perfect.

Then the system runs. Refrigerant and oil scrub the line walls at high velocity, the scale flakes off, and the flakes ride the flow until they hit the two finest screens in the circuit: the filter drier and the TXV inlet screen. From C11 you know the TXV meters refrigerant through an opening measured in thousandths of an inch, fed through a fine mesh screen. Scale plugs the screen, the TXV starves, suction pressure drops, superheat climbs, and you have a restriction call that diagnoses exactly like a failed TXV. The drier loads up the same way and becomes a liquid line restriction. The cruel part is the timing: the system runs fine for days or weeks while the scale migrates, so the callback lands on whoever brazed it, long after the truck left.

The fix costs almost nothing: displace the oxygen. Nitrogen is inert; it will not react with copper at any temperature a torch produces. Flow nitrogen through the line while brazing and there is no oxygen inside to burn. The inside of the pipe stays as bright as the day the copper was drawn.

The setup, building on the F2 nitrogen rig: regulator on the nitrogen cylinder, flow meter downstream of the regulator, hose into the line at a service port or an open tube end on one side of the work, and a deliberate exit path on the far side, an open port, a loose cap, or an un-brazed joint, so the nitrogen sweeps through the joint and out. Flow rate is 2 to 5 SCFH on the flow meter. Memorize the principle behind the number: a purge needs flow, not pressure. You are gently sweeping oxygen out of the pipe, not pressurizing it. Too little flow leaves oxygen pockets. Too much pressure does something sneakier: it pushes outward on the molten alloy and blows pinholes through the joint as it solidifies, so a heavy-handed purge creates the leak it was supposed to prevent. Set the flow before lighting the torch, verify you can feel gentle flow at the exit, and keep it flowing until the joint cools below glowing.

Trapped-pressure warning: if the line has no exit path, the heat itself raises the pressure of the trapped nitrogen, and that pressure will blow through the molten alloy. Always verify the exit is open before the flame touches copper.

IB STANDARD

Every Island Breeze braze flows nitrogen at 2 to 5 SCFH, verified at the exit before lighting. This pairs with the C15 standard: every opened system is evacuated to 500 microns with a decay test before charging. The two standards exist for the same reason. Clean and dry inside is the whole game, and neither cleanliness nor dryness can be added back after the fact. A plugged drier or TXV screen found on a post-install callback gets traced, and a dry braze is a training event, not a judgment call.

Brazing technique: heat the joint, not the rod

A good braze is mostly preparation. The flame is the short part.

Clean. Brazing alloy will not bond to oxide, oil, or dirt. Sand the tube end and the inside of the fitting cup bright with abrasive cloth or pad, the same deburring discipline from F2, then keep fingers off the cleaned surfaces. Skin oil is enough to make alloy crawl away from a spot.

Fit. Capillary action, the physics that makes this whole method work, is the tendency of a liquid to get pulled into a narrow gap by surface attraction, the same force that pulls water up a paper towel. Molten alloy gets drawn into a gap of 0.002 to 0.006 inch all the way around and all the way up the cup, even straight uphill, even on the blind back side you cannot see. Too tight and the alloy cannot enter; too loose and capillary action quits and the alloy just bridges the front edge. Seat the tube fully into the cup and check that it is straight, because a cocked tube makes the gap wrong on both sides.

Heat the joint, not the rod. This is the line every brazing instructor repeats forever, and it is the difference between a brazed joint and a glued-looking failure. The base metal must melt the alloy, not the flame. Bring the whole joint up to temperature with the flame moving, sweeping around the circumference, inner cone tip just off the surface, heating the fitting cup and the tube together until the copper glows dull cherry red. Then touch the rod to the metal at the edge of the cup, away from where the flame is pointing. If the joint is at temperature, the rod flashes liquid and capillary action snatches it into the gap, flowing toward the heat. You direct the fill by

moving the flame, because the alloy follows the heat. If the rod will not melt against the metal, the joint is not hot enough: pull the rod back and keep heating. Melting the rod in the flame and dripping it onto cold copper makes a blob sitting on top of an unbonded joint. It will look fine and it will leak.

On size differences within the joint, feed heat to the heavier mass. A tube entering a service valve or a compressor stub needs most of the flame on the heavy fitting, with the valve body itself protected: service valves get wrapped with a wet rag or heat paste because their internal seals die around 250 F, a number the surrounding brass reaches almost instantly during a braze.

Vertical joints: heat rises, so a cup facing down (tube pointing up into a fitting) fills easily. A cup facing up needs the flame biased low so the alloy is drawn downward toward the heat rather than pooling at the rim.

When the cup shows a complete fillet of alloy all the way around, stop. More rod does not make it stronger; it makes balls of alloy inside the pipe. Let the joint air cool until the glow is gone before quenching with a wet rag, because steam-quenching a glowing joint can crack the alloy.

Picking the rod: 15 percent silver phos-copper, and when flux enters

For copper to copper, the trade standard is a phosphorus-copper alloy rod with silver added, called phos-copper or by the BCuP classification. The 15 percent silver version melts around 1190 F, flows fully near 1475 F, and is the IB standard rod because the silver content makes it more ductile and forgiving on joints that see vibration. Its best trick is in the phosphorus: on copper, phosphorus chemically scavenges the oxide off the surface as the alloy flows, which means copper-to-copper joints need no flux at all. Lower-silver phos-copper rods (6 percent, 5 percent, 0 percent) are cheaper and flow fine on tight-fitting joints, but they are more brittle; on line sets that vibrate for two decades, the 15 percent rod is cheap insurance.

The phosphorus trick has a hard boundary: phosphorus plus iron or nickel forms brittle compounds. Phos-copper rod on steel or any iron-bearing alloy makes a joint that looks fine and cracks in service. So for any dissimilar joint, copper to brass, copper to steel, brass to steel, you switch to a high-silver alloy (BAg class, typically 45 to 56 percent silver, working roughly 1145 to 1400 F) and you use brazing flux, a chemical paste brushed on before heating that melts, blankets the joint, and dissolves oxide, doing the job phosphorus does automatically on copper. Flux residue is glassy and mildly corrosive, so it gets washed or brushed off after the joint cools. The field summary: copper to copper, phos-copper, no flux. Anything dissimilar, high-silver with flux. When in doubt about what a fitting is made of, a magnet and a scratch test answer most of it, and high-silver with flux is the safe default.

Silver solder vs brazing: the 840 F line

The terms get abused in the field, so settle them now. The American Welding Society draws the line at 840 F: a filler that melts above 840 F is brazing, below it is soldering. The base metal never melts in either process; only the filler does.

Soft solder, the plumbing material, is tin-based and melts around 450 F. Silver-bearing soft solder, the famous one being a tin-silver alloy that melts around 430 to 535 F, gets called "silver solder" at the supply house, and that name causes real damage, because a tech can hear "silver" and believe it is the same family as a 15 percent silver brazing rod. It is not. It is soft solder with a little silver in it. The temperature gap is nearly a thousand degrees, and the strength gap matches: a brazed joint is several times stronger than a soldered one and shrugs

off the 400 to 600 psi a high-pressure system can see, plus the vibration, plus Phoenix rooftop temperature swings. Soldered joints have legitimate homes, condensate piping, some water lines, certain low-pressure applications, but a high-pressure refrigerant line is not one of them, and IB does not put soft or silver-bearing solder on refrigerant circuits, period. If you cut out an old repair and the filler is dull gray and melted at the touch of a small flame, you have found soft solder on a refrigerant line, and you have probably also found the leak.

One useful upside of the temperature difference: brazing temperature anneals (softens) hardened copper, which is why a brazed line set near the joint bends more easily afterward. Expected, not a defect.

Swaging: tools and depth

A swage expands the end of one copper tube so the next tube of the same size slips inside it, forming the brazeable socket without a coupling. Fewer fittings, fewer joints, fewer chances to leak.

Three tool styles. The punch swage is a tapered steel punch driven into the tube end with a hammer, with the tube held in a flare block; cheap and fine for occasional use, but easy to split a tube with. The lever or expander swage squeezes expander segments outward inside the tube with a plier action; controlled, uniform, the standard service-truck tool. Drill-powered expander bits do the same job faster on repetitive work.

The number that matters is depth: the insertion depth of a swage equals the outside diameter of the tube. A 3/8 inch tube swages deep enough to accept 3/8 inch of the mating tube; 5/8 takes 5/8. Shallow swages do not give capillary action enough overlap to make a full-strength joint, and they also let the joint flex at the entry lip, which is where it eventually cracks. Soft copper swages easily; hard-drawn copper should be annealed first (heated to dull red and allowed to cool) or it splits at the rim. Inspect every swage for splits before brazing, because a split swage is scrap, not a candidate for extra rod.

Flare joints: the mechanical standard

Flare joints connect mini-split line sets, some metering devices, and most refrigerant accessories that need to be serviceable. The joint is a 45 degree cone formed on the tube end, clamped by a flare nut against the matching machined seat on the fitting. Metal against metal, no filler. Done right, it seals for decades and unscrews in thirty seconds when service requires it.

The making of a flare, expanded into the full procedure in the practical and the steps visual:

1. Cut the tube square with a tubing cutter, light pressure, several passes. Never a saw, per F2: chips kill circuits.
2. Deburr the inside edge completely, holding the tube opening facing down so the shavings fall out of the tube, not into it. A burr left in place gets folded into the flare face and becomes a leak path shaped exactly like a channel.
3. Slide the flare nut on first, open end facing the work. Every tech alive has formed one perfect flare with the nut sitting on the tailgate.
4. Clamp the tube in the flare block at the height the tool maker specifies, typically with the tube end slightly proud of the block face. Too low makes a short, thin flare; too high makes an oversized flare the nut cannot seat over.

5. Run the flaring cone down with steady, moderate force. An eccentric (offset-rolling) flare tool burnishes the cone smooth as it forms. Inspect: even width all around, smooth shiny face, no cracks or scoring. A drop of refrigerant oil on the back of the flare (never on the threads) helps it seat without galling.
6. Torque to the table with a torque wrench and crowfoot adapter, backing up the fitting with a second wrench so the line never twists. The values live in the Key Values table and in the manufacturer install manual, which wins any disagreement.
7. Leak test the joint: pressurize and bubble-test it, per the C15 nitrogen pressure test discipline, before insulation covers it.

Why torque is the religion here: under-torqued flares seep immediately. Over-torqued flares deform the cone, work-harden it, and crack weeks later, which is a worse outcome because it passes the day-one leak check. "Tight plus a grunt" is how mini-splits earn their reputation for losing charge. The torque table is how they keep it.

IB STANDARD

Mini-split flares are torqued to the manufacturer table with a torque wrench, every flare, both ends, and the value used is recorded in the job notes with a photo of the finished connection per the 8-photo close-out. This is the C16 habit that module A35 builds on: most mini-split refrigerant complaints in this market trace to a flare made by feel. Re-flare rule: any flare that is cracked, scored, or has been over-tightened gets cut off and remade. Flares are free; refrigerant and callbacks are not.

Press fittings: joining without flame

Press fittings for refrigerant lines (the zoom-style copper press systems rated for HVAC pressures) crimp a fitting onto the tube with a battery-powered press tool and interchangeable jaws. Inside the fitting, a high-pressure O-ring seals against the tube wall while the crimped profile grips mechanically. Rated systems carry pressure ratings at or above 700 psi, which covers R-410A and the A2L blends.

Where they belong: occupied and finished spaces where flame risk or fire-watch logistics are bad, deep attic insulation, close quarters near gas lines or wiring, and A2L service situations where eliminating the flame eliminates the protocol. Where they do not: anywhere the equipment manufacturer's instructions or the local authority having jurisdiction does not accept them, which you verify before pressing, not after. Warranty language matters here; some OEMs accept press joints on field piping, some do not.

Tool basics: cut square, deburr, mark the full insertion depth on the tube with a marker, insert to the mark, confirm the mark still touches the fitting, align the jaw square on the fitting bead, and complete the full press cycle without interruption. The two field failures are both preparation failures: a tube not inserted to depth (the mark drifts away from the fitting) and a nicked or scratched tube surface under the O-ring. Press fittings are permanent, not serviceable; service points still get flares or access valves.

A2L hot work: the changed rules

A31 covers A2L refrigerants in full. What belongs in this module is the hot-work boundary, because it changes what you just learned.

From the anchor set: R-454B is mildly flammable, with a lower flammability limit of 11.25 percent by volume in air, and its competent ignition sources are open flames and surfaces above 1290 F. Read that against this module: a brazing torch is an open flame running thousands of degrees past 1290 F. The torch is the single most competent ignition source you will ever bring near an A2L system.

So the rule is absolute. Never put a flame on a system that contained A2L refrigerant until all three are done:

1. Recover the refrigerant completely, with the A2L-rated recovery machine and flammable-rated cylinder per the F2 kit standard.
2. Purge the circuit with nitrogen, sweeping residual refrigerant vapor out of the lines, then keep the nitrogen flowing as the normal brazing purge.
3. Verify with the A2L leak detector at the work opening that no refrigerant remains, and keep area monitoring running for the duration of the hot work. The detector watches the space around you so a pocket of refrigerant from any source never builds toward that 11.25 percent number while a flame is lit.

And the guidance that surprises techs raised on R-410A: on A2L systems you cut the circuit open with a tubing cutter instead of unsweating joints with the torch. Unsweating a joint on a system with any refrigerant or saturated oil left in it puts flame on fuel. Cut it cold, then braze the new joint with nitrogen flowing after the purge and verification. Dry powder or CO2 extinguisher on site, vacuum pump and its switch positioned away from the work zone, A2L hoses and equipment only, all per the F2 A2L kit standard.

None of this makes A2L work exotic. Recovered, purged, verified, monitored: it is the same clean-system discipline this module already teaches, with a verification step added because the consequence of skipping it changed.

Common Mistakes

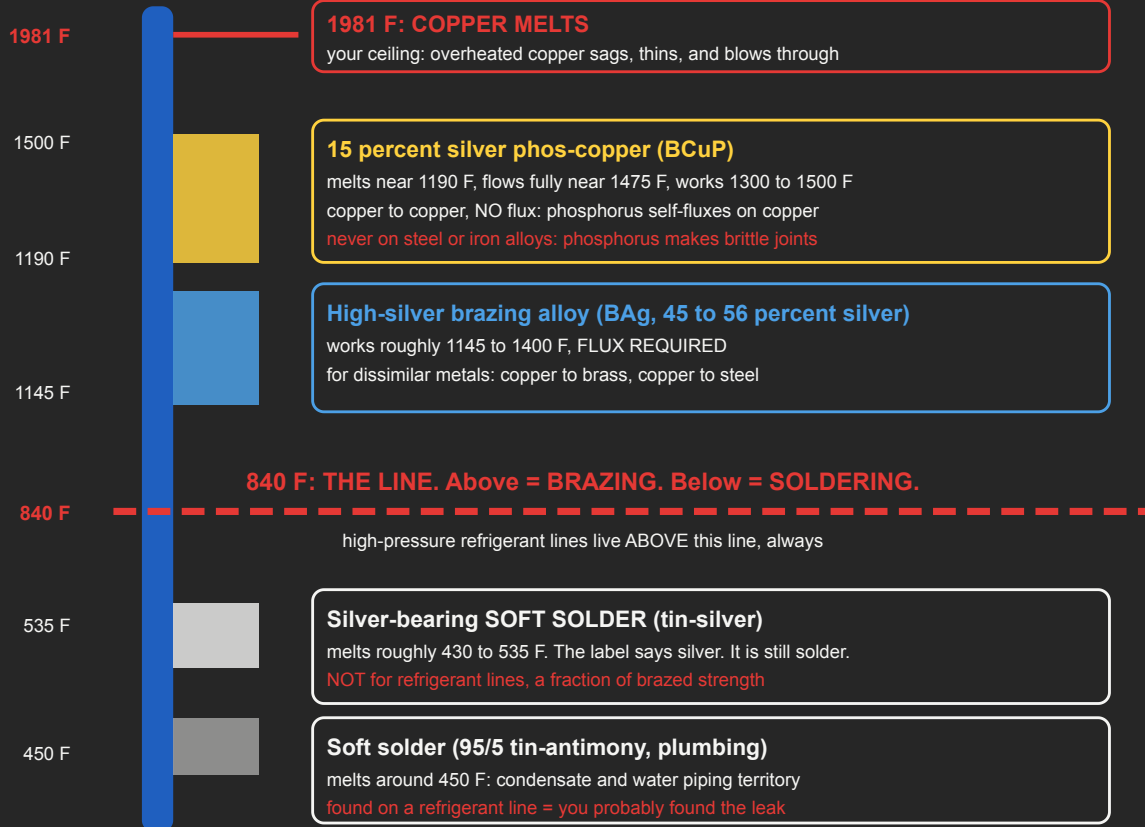
1. Brazing without nitrogen because "it is one small joint." Scale formation does not scale with joint count. One dry braze coats the line, and the TXV screen does not care how small the joint was. The callback arrives in two to six weeks wearing a restriction diagnosis.
2. Purging with pressure instead of flow. Cranking the regulator instead of metering 2 to 5 SCFH blows pinholes through the molten alloy, or pops the joint open as trapped pressure builds. Flow meter, gentle sweep, open exit path, verified before lighting.
3. Melting the rod in the flame. Dripping alloy onto copper that never reached temperature makes a surface blob with no capillary penetration. It passes a glance, sometimes passes a pressure test, and fails in service. The metal melts the rod, always.
4. Acetylene above 15 psig, or a cylinder used on its side. The first risks decomposition inside the hose, the second draws acetone into the regulator. Both are non-negotiable gas physics, not technique preferences.
5. Phos-copper rod on steel or dissimilar metals. The phosphorus that makes it self-fluxing on copper makes it brittle on iron. The joint cracks in service. Dissimilar means high-silver with flux, every time.
6. Calling silver-bearing soft solder "silver solder" and using it on refrigerant lines. It melts around 450 F and has a fraction of a brazed joint's strength. The supply house label says silver; the metallurgy says solder. High-pressure lines get brazed.

7. Flaring without the nut on, or skipping the deburr. The first wastes a flare. The second folds a burr into the sealing face and ships a leak. Nut first, deburr facing down, then flare.
8. Flares by feel instead of by torque table. Under-tight seeps now; over-tight cracks later and skips the day-one leak check entirely. The torque wrench and the manufacturer table are the whole answer, especially on 5/8 inch mini-split suction flares.
9. Skipping the fire watch, especially in attics and desert landscaping. Smoldering ignition reveals itself after you leave. Thirty minutes minimum, combustibles cleared to 35 feet or shielded, extinguisher staged before the striker clicks.
10. Putting a torch on a system that held A2L refrigerant without recovery, purge, and detector verification. With R-410A a shortcut like this burned oil and made acrid smoke. With an A2L it puts an open flame on a flammable refrigerant. Recover, purge, verify, monitor, and cut instead of unsweating. There is no version of being in a hurry that changes this.

BRAZE VS SOLDER TEMPS

The Temperature Ladder: Solder vs Braze

filler melt temperatures, base metal never melts in either process



A2L context: R-454B ignites from surfaces above 1290 F or open flame. Every brazing flame qualifies. Recover, purge, verify first.

FLARE MAKING STEPS

Making a Flare: Six Steps, No Shortcuts

1 CUT SQUARE



tubing cutter, light pressure, several passes. Never a saw.

2 DEBURR, FACE DOWN



tube opening DOWN
so shavings fall out,
not into the circuit

3 NUT ON, THEN BLOCK



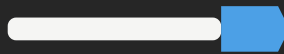
flare nut on FIRST, open end out
clamp at the height the tool
maker specifies, slightly proud

4 FLARE AND INSPECT



45 degree cone: even width, smooth
shiny face, no cracks or scoring

5 TORQUE TO THE TABLE



1/4 in: 10 to 14 ft-lb 3/8 in: 24 to 31
1/2 in: 36 to 45 5/8 in: 45 to 60

torque wrench plus crowfoot,
back up the fitting, manufacturer table wins

6 LEAK TEST



pressurize with nitrogen, bubble
test the joint BEFORE insulation
over-torqued flares pass today
and crack next month: use the wrench

IB STANDARD: every mini-split flare torqued to spec, value recorded, photo in the close-out.

JOINT TYPES

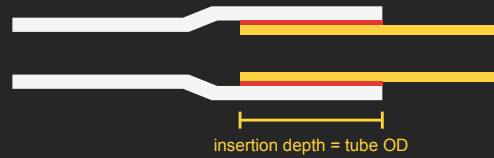
Four Joints, Cross Sections

1. BRAZE CUP (fitting joint)



alloy fills the 0.002 to 0.006 in gap by capillary action
filler melts above 840 F, base metal never melts
permanent, strongest, needs torch plus nitrogen

2. SWAGE (tube becomes the fitting)



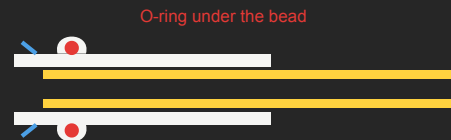
one brazed joint instead of two, no coupling
inspect for splits before brazing

3. FLARE (mechanical, serviceable)



45 degree cone clamps against machined seat, no filler
torque to the table: 1/4 in 10 to 14, 3/8 in 24 to 31,
1/2 in 36 to 45, 5/8 in 45 to 60 ft-lb (confirm per manufacturer)

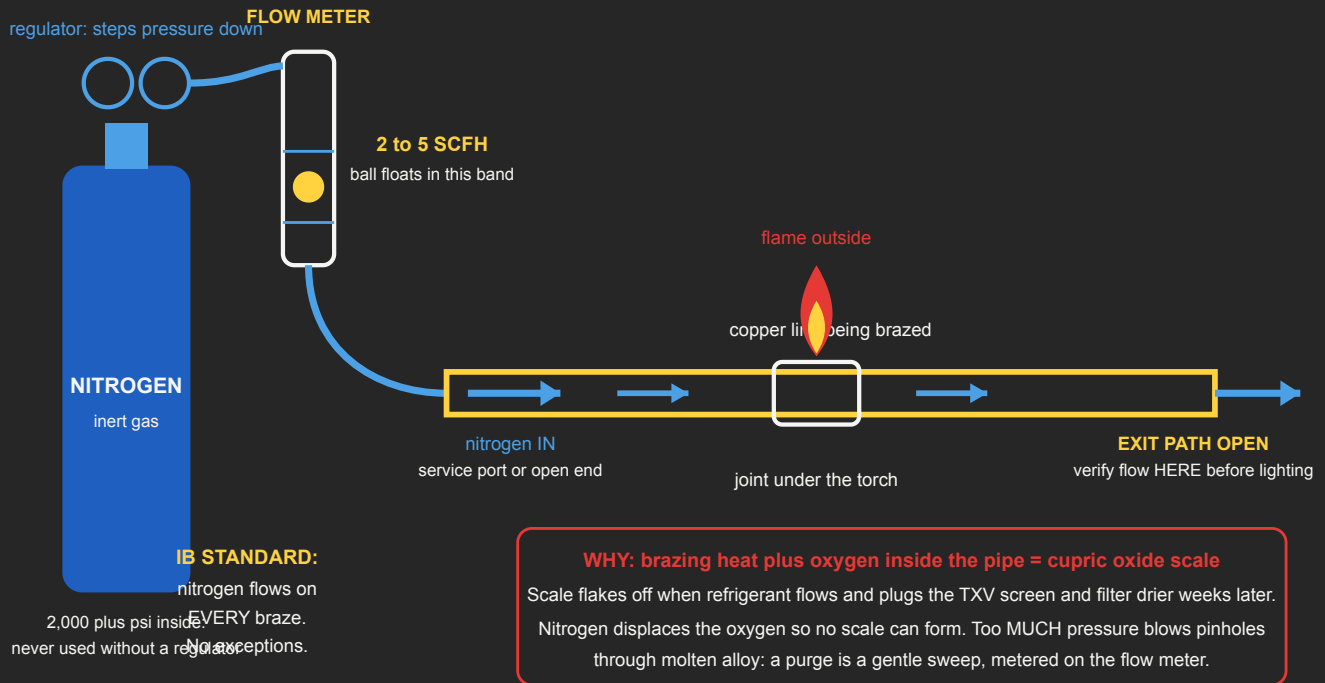
4. PRESS (no flame at all)



press tool crimps fitting onto tube, rated 700 plus psi
mark insertion depth, full press cycle, never serviceable
use where manufacturer and inspector allow: attics, A2L, finished spaces

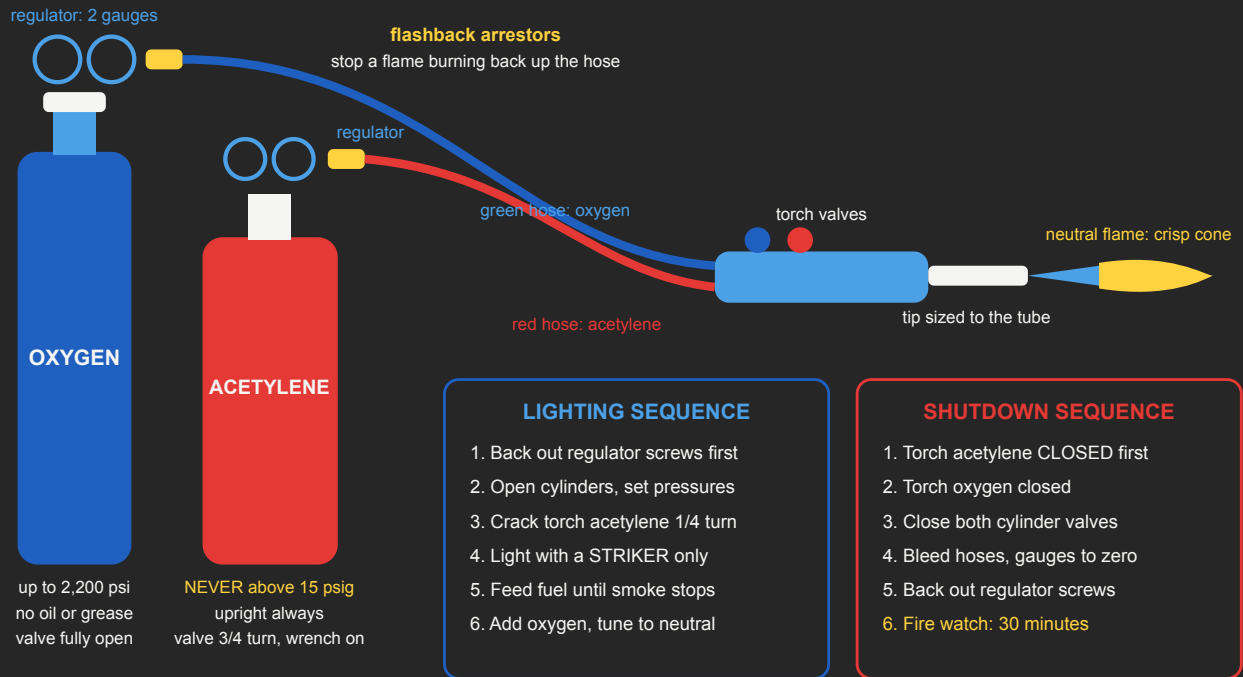
NITROGEN PURGE SETUP

Nitrogen Purge Setup: Flow, Not Pressure



TORCH ANATOMY SAFETY

Oxy-Acetylene Rig: Anatomy and the Safety Sequence



Cylinders secured upright. Combustibles 35 ft away or shielded. Extinguisher staged before the striker clicks.