Synergic Is Not Automatic

The Quarter Turn, and What the Curve Cannot See

Synergic control is not the machine setting everything, it is not some magical function, it is NOT pulse and it is not controlling your arc. It's simply a library of settings that is stored in the machine's memory and it sets the machine based on a preset relationship between amps and volts, built from three inputs, wire type, wire size and shielding gas that somebody measured once to create a ‘synergic line’. You set the amps, then you ‘trim’ the voltage. Trim is the quarter turn you give it when the job in front of you isn't the same as the preset values.

A TECHNICAL ARTICLE ON SYNERGIC GMAW, WHAT IS IT, WHAT THE STORED CURVE ASSUMES, AND WHAT MOVES IT

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Four different people misunderstand synergic welding in four different ways, and I've had all four conversations this year. And it matters as this forms part of competence.

The welder thinks the dial sets amps. The supervisor thinks trim is a heat knob. The salesperson thinks the machine sets everything, because that is what the sales brochure said. And the fab shop owner thinks they are buying a productivity gain.

Every one of those ideas came from the way the machines are sold, the way the manuals are written and the fact very few people take the time to explain it properly. So here's what is actually **going on inside a synergic machine**, what it is, what it is not and how to get the most out of it.

Where the Word Comes From

Straight from the Greek. *syn*, together, plus *ergon*, work. **Synergia meant joint work, cooperation.**

It arrived in English in the 1650s as a theological term for human will cooperating with divine grace, and Jacob Henle picked it up in 1847 to describe the concourse of action between different organs. The meaning everybody now assumes, greater than the sum of the parts, is late. It dates to about 1957, it was popularised through Buckminster Fuller, and it was borrowed from pharmacology and metallurgy where two substances together did more than either alone.

Then the management consultants got hold of it.[1]

That history matters, because synergic control isn't that kind of synergy. **One plus one does not equal three inside a welding machine.** It's the older and truer meaning: two things working together instead of against each other. No extra output. Just cooperation instead of argument.

Where It Comes From in Welding

Not marketing. It's a research term, it's British, and it's traceable to one researcher.

M. Amin, *Synergic pulsed MIG welding*, Metal Construction 13(6) 349 to 353, 1981.[2] Three more papers followed over the next six years, ending with Amin and Ahmed, *Synergic control in MIG welding*, in 1987.[3]

So the term is about **forty-five years old**, and it was coined for a specific problem. Pulsed MIG had too many independent variables for a human to set at the machine: peak current, background current, pulse frequency, pulse width, ramp rates. Amin's answer was to make all of them follow one input.

The usual line is that the Poms invented it and we improved it. Not this time. Britain named it, and Australia already had it running. Graeme Ogilvie started exploratory experiments at the CSIRO Division of Tribophysics in 1978, and had a thyristor pulsed current generator working in 1979, two years before Amin's paper reached print. Welding Industries of Australia took it to market in September 1983 as the Synchro-Pulse CDT, Controlled Drop Transfer, with arc voltage and current sensing fed back to hold the drop transfer steady. The machine welded Australia II and the flagpole on Parliament House, and it sold into shipbuilding overseas on aluminium and stainless, where the welds had to be right.

And this is where the confusion starts, because the CDT was both. A **pulsed transfer process and a synergic control**, in the same box, in 1983. Load a program, turn one knob, and the machine scheduled the waveform off it. Two words for two different things, welded together in one product, and the trade has used them interchangeably ever since. It was a fabulous piece of gear, and the front panel of a CDT 450 is this whole article in a box: two knobs, ARC CURRENT and ARC LENGTH. One to set ‘heat or energy’ along the line, one to ‘trim the voltage’ of the line.

From the beginning, they weren't widely understood, and when, as an apprentice, I first asked the tradesman, "Is the new synergic machine any good?" as I was really keen to have a shot, he responded with, "Yes, the sparks don't even burn." I found out that wasn't the truth pretty quickly.

The CDT was widely known to run an arc length too long for most applications. Which is exactly what the second knob, ‘arc length’, was intended for. Often you would run out of adjustment. And it was exactly the knob nobody was taught to use. If only I knew then what I know now. All I had to do was increase the length of the earth lead, and it would have instantly fixed the long arc.

It Is Not Controlling the Arc

This trips up nearly everybody, including a fair few of the people who sell these machines.

A synergic line isn't arc control. It's just **a relationship between amps and volts**, built from three inputs: wire type, wire size, gas type. That is it. Somebody did a heap of work to establish what the volts should be for the amps across every combination of those three, and the machine holds the answer.

Compare the two. Non-synergic MIG gives you two knobs that must agree. Wire feed speed sets the current, through the burn-off relationship. Voltage sets the arc length. Only a narrow band of pairings works. Get it wrong one way and you stub the wire into the plate. Wrong the other way and you get a long harsh arc, spatter and undercut. Synergic control stores the pairings that work. You set one variable, the machine reads off the matching one, and in pulsed mode every pulse parameter with it.

[1] Online Etymology Dictionary, entries for synergy and synergism. Greek synergia, joint work, from synergos: syn plus ergon. English 1650s, theological, now obsolete. Henle 1847 for the concourse of action between organs. The modern sense by 1957.

[2] Amin, M., Synergic pulsed MIG welding, Metal Construction 13(6) 349 to 353, 1981. Metal Construction grew out of Metal Construction and British Welding Journal.

[3] Amin, M., Pulse current parameters for arc stability and controlled metal transfer in arc welding, 15(5) 272, 1983; Microcomputer control of synergic pulsed MIG welding, 18(4) 216 to 221, 1986; and with Ahmed, N., Synergic control in MIG welding, 19(1) 22 to 28, 1987. Verified against the reference list in Concept of Pulse Current Gas Metal Arc Welding Process, Springer, 2017. Two reference lists give the 1983 end page as 278 and one as 287, so only the start page is quoted.

Synergic is not pulse, it is not a waveform. It is a series of presets, it is the modern version of a ‘welder's settings notebook’ that welders keep in their toolbox. That said, you can get synergic pulse, and in fact most pulse machines are synergic.

Now to the bit that matters. **On a plain synergic CV machine, nothing in there is controlling your arc.** The arc is held by ordinary constant voltage self regulation, the same physics that held it before synergic control was invented: when the current rises the wire burns off faster, so the arc length restores itself. That happened on a 1960s machine and it happens on yours. The synergic layer **never touches it**. All it does is save the operator from guessing the voltage. It provides a starting point.

Where real arc control does exist, it's a separate layer bolted on top and it is **not the curve**. In synergic pulse a waveform controller estimates arc length from the voltage and current on the pulse ramps and corrects it inside individual pulse periods. In an adaptive machine there is a stick-out compensation loop with a declared envelope. Both are closed loop control. Neither of them is the synergic line.

So the curve is a lookup table with interpolation. Not intelligence, and not control. Interpolation is like joining the dots with a ruler. The equipment manufacturer measured four settings, 100, 150, 200 and 250 amps for example, the machine draws a line between them, and every setting you pick in between comes off that line, not off anything anybody actually welded at that setting.

Two things worth cementing before we go on.

- **Synergic is how the machine gets set up**. Pulsed is how the metal crosses the arc. Plenty of welders think one means the other, and so do plenty of the people selling it.
- **The machine can't tell** what's loaded. Not the wire, not the diameter, not the gas. There's nothing in there that senses any of it. All it holds is a relationship between amps and volts, and what you selected is only a pre loaded relationship. So don't stand there thinking you haven't got a line for your combination. Load one that's close, trim it to suit, and write the trim down.

That last one matters more than you think. You select three things. The curve assumes two more and never asks about either: **the mode of metal transfer, and the stick-out it was measured at.**

Neither is on the panel, and neither cares whether you got the first three right.

The Quarter Turn

Think about a two-stroke. Chainsaw, dirtbike, whipper snipper, whatever you've got out the back. The factory set the carburettor needles for one fuel, at one altitude, at one air temperature. At sea level on 91 octane at 5 degrees C it runs sweet.

Take it up the hill, use it in 35 degrees C weather or change the fuel, and you give the needle **a quarter turn** to suit. Nothing stops you running the factory setting anywhere you like. It just runs rich or lean, and the only thing telling you is how it sounds and the amount of smoke.

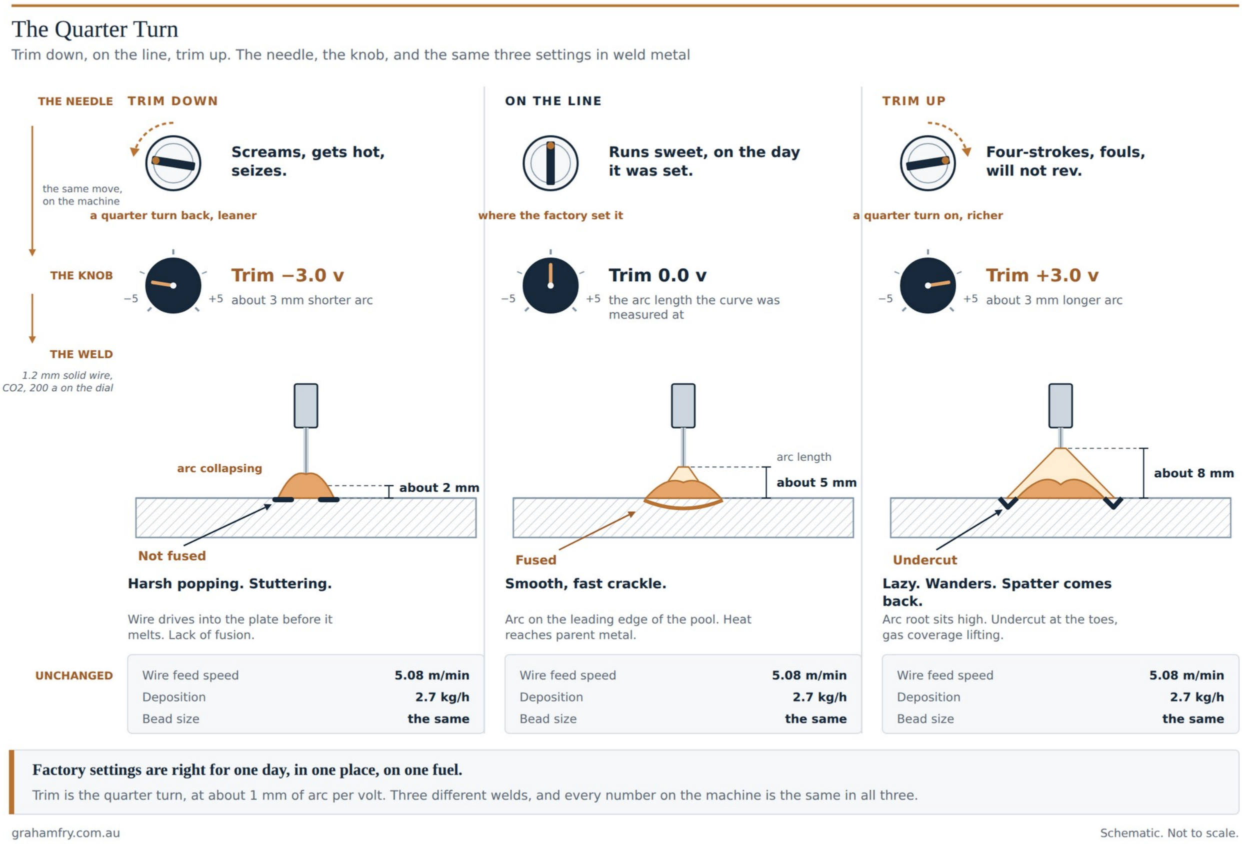
That's a synergic machine. The stored curve is the factory setting. Trim is the quarter turn. And the arc is what you are tuning often by sound.

Wind it lean and it screams and seizes. Wind trim down too far and the wire stubs into the plate before it melts: harsh popping, stuttering, whiskers, and lack of fusion.

Wind it rich and it four-strokes and fouls. Wind trim up too far and the arc goes long and lazy, the arc root lifts off the leading edge of the pool, and you get undercut at the toes.

Same knob. Same two extremes. Same feedback, which is your ears and eyes.

Figure 1. The Quarter Turn. Trim down, on the line and trim up: the needle, the knob, and the same three settings in weld metal underneath.



Schematic. Not to scale. Arc root position is drawn deliberately: the defect at trim high is that the arc lands beyond the toes of the pool.

What the Curve Actually Is

The table is smaller than anyone imagines. A Migatronic synergic program holds **three curves of four calibration points each**, with straight lines interpolated in between, and the machine will throw an error and refuse a point that isn't monotonic.[4] Four points. Nothing between them was ever measured.

Manufacturers rarely publish their curves, but consumable makers publish the same information in the same shape. Select-Arc gives four rows per diameter for stainless wire, and that is a published synergic line in all but name.[5]

The best definition in print is Norrish, at Wollongong, which makes it the right one to quote at an Australian reader. Synergic control is any system by which a parameter is amended such that **an equilibrium condition** is maintained over a range of wire feed speeds.[6]

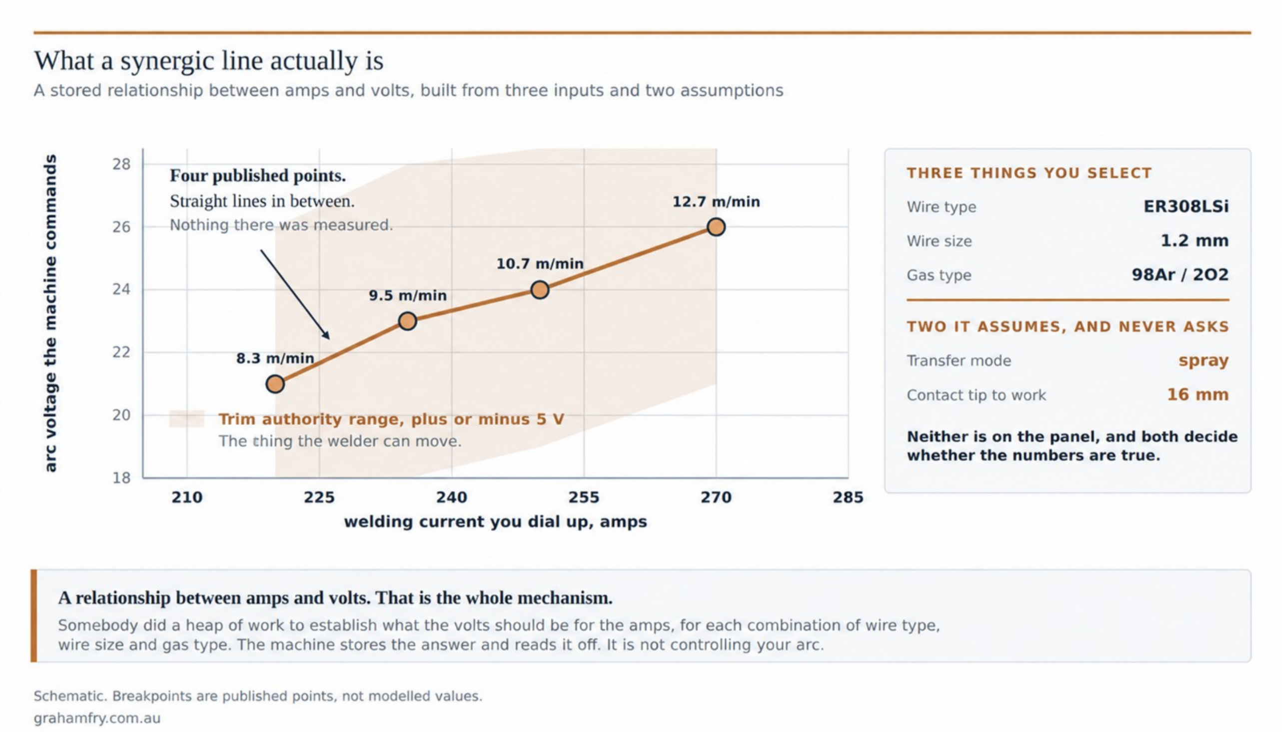
That word equilibrium is the one every manual drops. The machine isn't clever and it isn't watching you. It's holding one balance, the one where the wire burns off exactly as fast as it's fed, and it holds it by looking the answer up from the ‘preset estimated values’.

[4] Migatronic COMMANDER BDH MIG Instruction Manual, 50173001A. Three curves per synergic program, four calibration points each, linear interpolation between, and error Err A- on a non-monotonic breakpoint.

[5] Select-Arc, Select 308LSi data sheet, 17 April 2024. Recommended welding parameters, four rows per diameter, 98Ar / 2O2.

[6] Norrish, J. (2017), Welding in the World 61(4) 755 to 767, doi 10.1007/s40194-017-0463-8. University of Wollongong.

Figure 2. One real published curve. Three inputs you select, and two the curve assumes without asking.



Breakpoints transcribed from Select-Arc Select 308LSi recommended welding parameters, 1.2 mm, 98Ar / 2O2. Schematic; the straight segments between rows are interpolation, not measurement.

The Three Units

The machine does the misleading here, and it does it with the units.

Many synergic interfaces let you dial the primary knob (energy or heat) in amps, or in millimetres of plate thickness, or in metres per minute, and the machine converts. EWM is the only maker I've found that puts all three readouts on the panel and says plainly that they're the same setting.[7]

So you dial 200 and believe you've set 200 amps. You haven't. You've selected a point on a curve, and the machine has commanded a wire feed speed and a voltage from it. The current that comes out the other end is an **outcome**, and it depends on your stick-out, your earth return, your contact tip and your circuit resistance. The machine knows none of those.

So pick one unit for setting your machines and stay with it across your shop. A shop where one welder dials amps, the next dials plate thickness and the third dials metres per minute has three different mental models of the same machine, and not one of them lines up with what the procedure sheet asks for. In my opinion amps is the one worth standardising on, because amps is the number that appears on every sheet and every report you will ever have to defend, the one arc energy is derived from and the one that matters.

In my opinion the manufacturers' efforts to simplify the machines have mostly just confused the users, because they think it's three different things.

Trim Is Not a Heat Knob

Trim is a bias on the settings table's output. Nothing more. It's roughly plus or minus 5 v of authority, which at about a volt per millimetre of arc column is about 5 mm of arc length, far more than any real tweaking of a process needs.

What it acts on depends on the mode, and this is where a lot of the confusion lives. In synergic CV it is a voltage offset on the stored curve. In synergic pulse it is an arc length target that the controller services by moving the **background current**, which Kemppi documents explicitly.[8]

[7] EWM Picomig 185 Synergic TKG operating instructions, 099-005548. Operating point shown as current, plate thickness or wire feed speed.

[8] Kemppi FastMig Pulse operating manual. FineTuning minus 9.0 to plus 9.0 v, 0.5 v steps, on base current and arc length.

What it is not is arc dynamics or inductance, and often these two are confused. Trim and arc dynamics are different things, and I'll leave that for a separate article. We just need to delineate the two: trim adjusts voltage, which is arc length.

On a Lincoln, trim does not apply in CV modes at all, it adjusts arc length in pulse, and in STT it does change heat input, by adjusting the tailout and the background.[9] One word, one knob, three different jobs depending on which mode is loaded.

So when a welder is confused about trim, that isn't them being thick as two short planks. That's because we haven't been consistent or taught them properly. They transfer the learnings from the last machine.

The naming doesn't help either. Cigweld, which has the deepest trade recognition in this country, calls the arc length offset **Heat Control** on the Transmig 355i.[10] It isn't a heat control. It doesn't touch the commanded wire feed speed, so deposition doesn't change and the current barely moves. It changes arc length. Call it heat and you send a welder chasing a fusion problem with the wrong knob.

I often get people referring to voltage as 'heat'. And the reason is that as you increase arc length, you increase visible light, weld pool fluidity and weld width. So the arc appears to be hotter.

The arc energy calculation supports it: amps times volts over travel speed. But the reality is the majority of the energy comes from amps and it needs to, we feed more wire, we need more energy to burn that wire off. Amps is synonymous with wire feed.

Don't go looking for a volts equivalent to the Lincoln scale. Lincoln doesn't publish one, and the manual explains why: when pulse welding, the arc voltage is highly dependent on the waveform, and the peak current, background current, rise time, fall time and pulse frequency all affect it.[11] A trim of 1.00 isn't a fixed voltage. Change the wire, the gas or the wire feed speed and 1.00 is a different number of volts.

One knob, nine names, and none of the numbers transfer

Maker and family	What it is called	Range and units
Migatronic, EWM Phoenix	Arc length correction	minus 9.9 to plus 9.9 volts
EWM Picomig	Arc length correction	minus 5 to plus 5 volts
Kemppi FastMig, X5, Master M	Fine tuning	minus 9.0 to plus 9.0 volts, 0.1 or 0.5 v steps
ESAB Aristo U8, U82	Offset from the synergic line	volts, 0.25 v steps
Cigweld Transmig 355i	Heat Control	up to plus 5 volts from preset, 0.1 v steps
Fronius TPS/i	Arc length correction	minus 10 to plus 10 per cent of the curve value
Cigweld BlueVenom XF353[12]	Volts Trim (TRIM/V)	minus 5.0 to plus 5.0 volts
Lincoln Power Wave, Power MIG	Trim	0.50 to 1.50 dimensionless, no volts published
Millermatic and Multimatic 255	Arc Length	0 to 99 dimensionless index

From each maker's own operating instructions. The European brands express the control in volts and the American brands as a dimensionless number, so a welder moving between two machines in the same shop is turning knobs measured in units that do not convert.

[9] Lincoln Power Feed 15M operator manual. Trim not applicable in CV. In STT it changes heat input via tailout and background.

[10] Cigweld Transmig 355i operating manual. Heat Control, 0.1 v steps to plus 5 v from preset.

[11] Lincoln Power Wave 455M operator manual, page 28. In pulse, preset voltage is impractical, so trim is the control.

[12] Cigweld BlueVenom XF353 operating manual 0-5708, part W1400353, 27 March 2024, section 5.15. Volts Trim, minus 5.0 to plus 5.0 v applied to the QuickSet synergic voltage. The display reads Syn when trim is at zero.

Which raises the practical problem.

Write +2 v on a WPS and that instruction only means something on a machine that expresses trim in volts with exactly the same setup, in particular ‘total lead loop length’ (interconnecting leads + earth + torch) and in the mode it was measured in.

Hand the same sheet to a shop running a different machine and you haven't made it simpler. You have created confusion. The value that matters is arc voltage, measured with a decent tong tester from wire feeder to job. Do not rely on the digital read out.

This is a large part of why a procedure qualified on one machine does not travel to the next one and produce the same result. And it's not the welder's fault. It's the responsibility of the welding supervisor / coordinator to manage these differences and train the welders.

You Can Run Any Line With Any Wire and Any Gas

Nobody tells you this part. And I have experienced this more than once, where someone says, "I can't weld this material with this wire because I don't have a program in my machine for it."

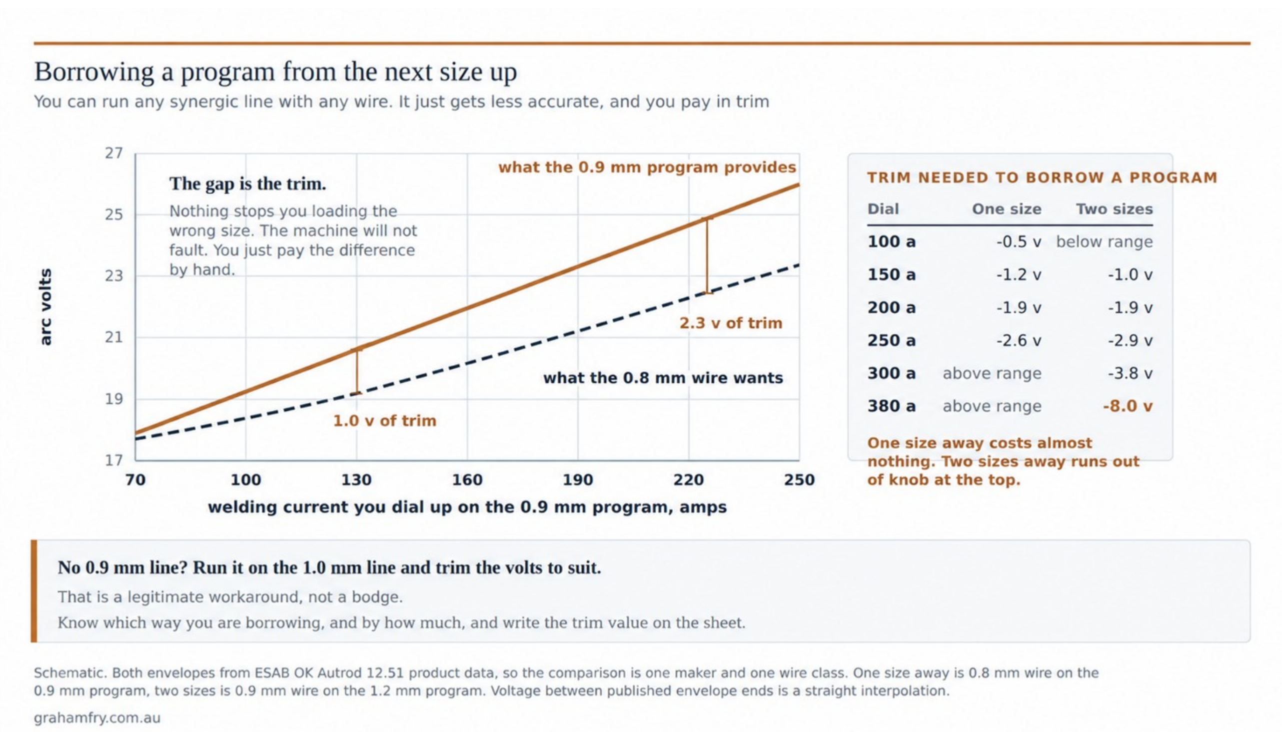
Nothing stops you running the wrong program. The machine won't fault. It won't warn you. It'll weld, and it'll put a bead down that looks like a bead. No 0.9 mm line in your European machine? Load the 1.0 mm line, run the 0.9 wire on it, and trim the volts to suit. Thats a legitimate workaround and I wouldn't blink at a welder doing it, I would praise them.

What it costs you is ‘accuracy of the starting point’. The curve has stopped doing the work, and you're doing it by hand.

The extent of that cost is calculable, and it's smaller than you'd think one size away. Take ESAB's own published envelopes for one wire class so the comparison is honest.[13] Run 0.8 mm wire on the 0.9 mm program and you need about half a volt of trim at 100 a, rising to 2.6 v at 250 a. Go two sizes, 0.9 mm wire on the 1.2 mm program, and you need a volt at 150 a, near 3 v at 250, and 8 v at 380, which is off the end of the knob.

So the rule's simple. One size away is nearly the same at the bottom of the range and the variation (trim) gets greater as you wind it up. Two sizes away runs out of trim at the top. And the gap always widens as current increases, which is why the ‘it ran beautifully on 3 mm plate’ falls apart when the same welder goes up to heavy material.

Figure 3. Borrowing a program from the next size up. The vertical gap between the two lines is the trim you have to put in by hand.



[13] ESAB OK Autrod 12.51 product data sheet, cross-checked against Cigweld Autocraft LW1-6 for the metric ranges.

Both envelopes from ESAB OK Autrod 12.51 product data, one maker and one wire class. Voltage between published envelope ends is a straight interpolation. Schematic.

Gas is the same story, and Lincoln details it on one page. For 1.2 mm L-56 they publish 100% CO_2 at 19 to 21 volts and 145 to 200 amps, short circuit. The same wire in 90 argon 10 CO_2 they publish at 27 to 30 volts and 285 to 340 amps, spray. Same wire, same sheet, and CO_2 sits right down the bottom.[14]

That's not a small difference, it's a different arc. Argon is a single atom and ionises into a smooth, stable column. CO_2 has to be torn apart in the arc before it will conduct at all, and it can't produce spray at any current. So wind the volts up on CO_2 expecting a nicer arc and you don't get one. You get globular: big droplets, and what Lincoln's own guide calls difficult to control with severe spatter. What I call "runs like a pig". Ferocious, in other words. A CO_2 procedure runs low volts on purpose.

So which way does the trim go? Load a spray tuned argon program, run CO_2 on it, and you'll be winding down, several volts, and you still won't get spray, because CO_2 can't.

Running straight CO_2 in modern welding equipment and workshops is false economy. It is particularly so with the declining skill level of welders: you're giving them a more difficult process to manage with an arc that's erratic and runs poorly.

We need to get smarter about the value of process control. And don't try and save money with gas whilst making the welder's life harder, all while decreasing metal recovery rate of a process because it's spattering like all get out.

I'll keep an in depth review of the CO_2 shielding gas topic for a separate article because people do not truly understand the economics or the practicality of it, and that whilst they think they are saving money, they're having a detrimental effect on quality and productivity.

Record the volts on the WPS, measured at the right place with the correct equipment. You can make a note of the trim value on the sheet, just educate your welders of the limitations of the information.

There is a necessary discipline here. A program with the 'trim' recorded is not necessarily a process control mechanism. What appear to be minor changes can significantly throw off the accuracy of that value, and then just serve to confuse those using the equipment.

The Four Things the Curve Cannot See

The machine reads its own output terminals. That's the entire extent of its awareness, in 99 per cent of cases.

Four things sit outside it, and all four move the arc characteristics away from the number on the wire feeder display.

Stick-out is the expensive one. Miller measured 282 amps falling to 213 a as the contact tip to work distance went from 15.9 to 25.4 mm, which is **7.3 a per mm**.[15] EWI measured 300 a falling to 225 a from 19.1 to 28.6 mm on a pulsed procedure, 7.9 a per mm.[16] Both at unchanged machine settings. The burn-off equation predicts 6.6 a per mm at 300 a from published coefficients with no fitting, which is about as good as this class of model gets.[17]

Work an example. Lincoln publishes 200 a at 21 v for 1.2 mm solid wire in CO_2 at a nominal 16 mm. Reach into a joint, stick-out out to 25 mm, and the arc receives about 174 a. **Thirteen per cent of your current (amps), gone, with nothing on the machine touched.** Wire feed speed hasn't changed, so deposition hasn't changed and the bead is the same size. Fusion isn't. This is the leading cause of lack of root fusion in GMAW.

That's an increased risk of lack of fusion on a machine that was set right to the WPS, and it's the most common way I see a perfectly good procedure produce a non-compliant weld and therefore a costly repair.

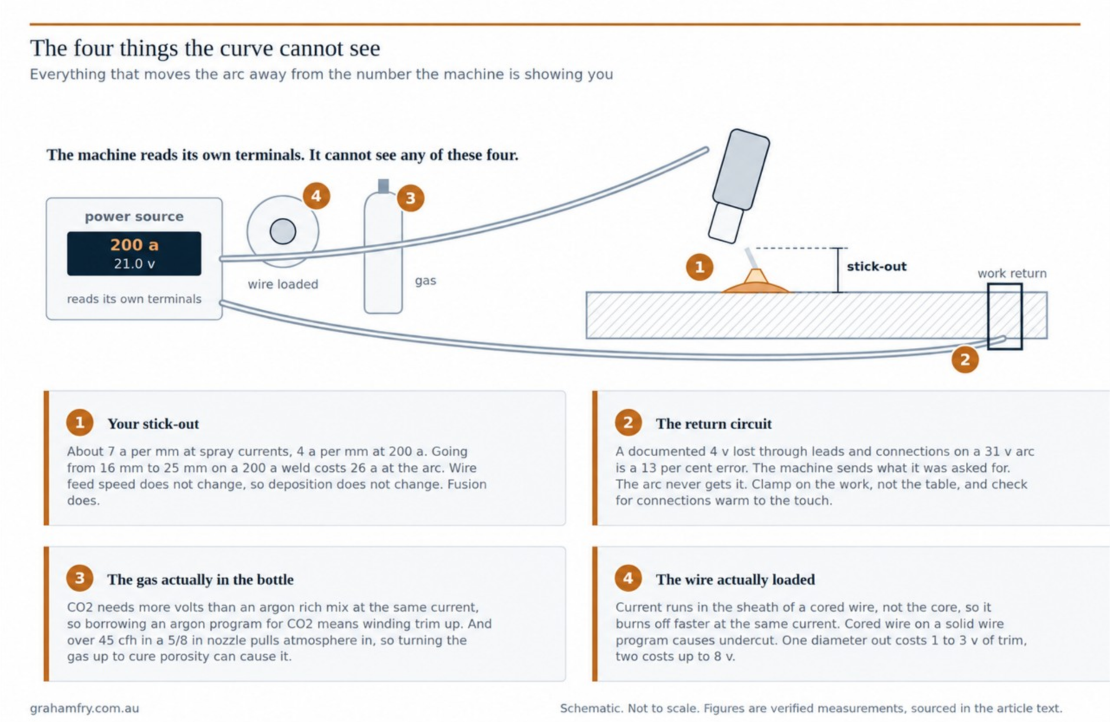
[14] Lincoln Electric SuperArc L-56 data sheet

[15] Miller Electric, What Are Stickout, Electrode Extension and Contact-Tip-To-Work Distance. GMAW spray, 15.9 to 25.4 mm, 282 a falling to 213 a.

[16] EWI, A Green Perspective on Arc Welding Part 1: Harnessing the Power of Resistive Heating. GMAW-P at 200 in/min, 19.1 to 28.6 mm, 300 a falling to 225 a.

[17] Richardson, I.M., Bucknall, P.W. and Stares, I. (1994), Welding Journal Research Supplement 73(2) 32s to 37s. Burn-off coefficients fitted at 15 mm extension.

Figure 4. The four things outside the machine's awareness, with what each one costs.



Schematic. Not to scale. Every figure in the callouts is a verified measurement, sourced in the text.

Total lead length, and the earth return circuit in particular, is an invisible error. The machine's voltmeter reads at its own terminals, so it always reads high. A documented case put 4 v across the leads and connections on a 31 v arc, which is a **13 per cent error, and needed 35 v at the supply to deliver 31 v** at the work.[18] The machine sent what it was asked for. The arc never got it. So the trim goes up to make up the difference, and now you've got two faults stacked on each other. Clamp on the work, not the table, and put a hand on the connections after a run. Warm means resistance.

Gas, the machine cannot sense at all. Not what's in the bottle, not the flow, not a leak. It's variation in composition that is the biggest determining factor, because there's no such thing as one argon CO2 mix.

Some countries run 80% argon 20% CO2, others run 82/18, and then there are the tri mixes, argon with 16% CO2 and 3% O2. Under ISO 14175 the first two are both M21, which covers anything from 15 to 25 per cent CO2. The trimix is M26, and your machine may not have a program for it at all.

Then look inside the designation. ISO 14175 lets any component above 5 per cent be delivered within plus or minus 10 per cent of its nominal value. Not ten percentage points, ten per cent of the number. So a nominal 20 per cent arrives anywhere from 18 to 22 per cent, a nominal 18 arrives anywhere from 16.2 to 19.8, and both are fully compliant.

That's nearly six percentage points of CO2 across two gases the machine treats as one program, and it has no way of knowing which bottle it's being fed from. This is enough to change how the arc sounds, and enough to want a volt of trim to compensate for the variation in shielding gas.

The wire. Two spools can both say ER70S-6 and still run differently, because the standard allows a range, it is not an exact number. AWS A5.18 allows manganese anywhere from 1.40 to 1.85 per cent and silicon from 0.80 to 1.15 per cent. Those two are the deoxidisers[19], and they set how the pool wets, how the arc forms and how much silicate island you get left on top.

A wire at the bottom of both bands and a wire at the top are both compliant ER70S-6, and they don't run the same. Add the diameter tolerance, and copper coating on some and none on others, and you have an accumulation of small differences that are enough to throw it off the

[18] American Welding Society member forum, Volts and Amps at Power source or at Arc. A 4 v drop through leads and connections on a 31 v arc. With short leads the difference is negligible.

[19] AWS A5.18/A5.18M, Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding. ER70S-6 required composition, per cent by mass: C 0.06 to 0.15, Mn 1.40 to 1.85, Si 0.80 to 1.15, P 0.025 max, S 0.035 max, Ni 0.15 max, Cr 0.15 max, Mo 0.15 max, V 0.03 max, Cu 0.50 max. Dimensional tolerances for solid and tubular electrodes are in ISO 544.

synergic line and you need to use the trim knob to bring it back.

Two examples of why that matters more than it sounds. Silicon is a powerful resistivity raiser in iron, and resistivity is what heats the stick-out. ER70S-6 allows silicon anywhere from 0.80 to 1.15 per cent, so two compliant wires don't heat the same on the way to the arc and don't burn off at the same rate at the same current.

And the wire isn't only the thing being melted. Iron vapour ionises at 7.9 electron volts against argon's 15.76, so metal vapour coming off the wire is a large part of what carries the current in the arc column. Change the chemistry and you've changed the conducting medium, not just the filler. Not all wires carry the current the same.[20]

None of that is on the panel and none of it is in the program. It comes out as a wire that wants a different trim to the last one, on the same job.

Then you change product type from solid to a cored wire and it stops being a small difference. Current runs in the metal sheath, not the core, so the conducting area is an annulus rather than a circle and the wire burns off faster at the same current.

1.2 mm metal cored deposits 5.4 to 6.4 kg an hour against 3.6 to 4.5 for solid the same size. Sheath thickness is the maker's own choice, so even two cored wires of the same class and the same diameter don't have the same conducting area. Run any of it on a solid wire program and you get undercut and you will be miles away from the line.

Trim set at the limits is telling you something.

I have not seen this written down anywhere.

Wires aren't all the same, and nor are gases. A change in total cable length and diameter, the earth in particular, is the very reason the ‘trim’ setting can vary so much between machines from one fab shop to the next.

That's all documented. A gun welder will know ‘what 28 v looks like’ for a given wire size, wire type and gas combination. They're able to adjust the machine from the arc, rather than the numbers the wire feeder is displaying. Others won't, and that's where your lack of process control creeps in.

If a welder consistently needs a lot more or less volts than the curve suggests, the curve isn't wrong. One of three things is, and every one of them is a five minute check.

- The stick-out is too long. The extra extension resistance has dropped the current, so the curve's voltage is now too low for the arc that is actually there.
- The program doesn't match what is loaded. Wrong diameter, wrong wire type, or the gas got swapped and nobody changed the program.
- Volts are being lost between the terminals and the arc. Leads length and diameter, connections and work return.

So do an audit and ‘record the trim’ value next to the current on every machine in the shop. A fleet of machines sitting near nominal has the right programs, has been set up properly and the welders are holding the correct stick-out.

If your machines are sitting on the limits of the trim or beyond plus or minus 3 volts, that is telling you something needs addressing. Costs nothing but a bit of time to find out, and it's the closest thing to a free diagnostic the equipment offers.

What the Display Is Worth

Three errors stack up, and most fab shops know about none of them.

The first is the averaging error on a waveform. Our very own John Norrish's measured spot checks at 5 kHz put conventional spray transfer at zero error, conventional dip at 8.3 per cent the **wrong way**, and pulsed transfer at plus 23 per cent, where the naive calculation understates the true arc energy.[21] Read that again, because the sign reverses. If you're holding an upper arc energy limit on a quenched and tempered or TMCP steel and you're welding pulsed, your paperwork is optimistic. And the consequence downstream is bigger than the input error: on the dip case an 8 per cent error in arc energy became a 46 per cent error in the calculated cooling time, because that relation is not linear.

The second is the instrument itself. A standard grade power source, one built to the

[20] Iron ionisation energy 7.90 eV against argon's 15.76 eV. On metal vapour as part of the conducting column: Murphy, A.B. (2010), Metal vapour causes a central minimum in arc temperature in gas metal arc welding through increased radiative emission, Journal of Physics D: Applied Physics 43, 022001.

[21] Norrish (2017), table 3. Arc energy at 5 khz sampling: spray zero error, conventional dip minus 8.3 per cent, controlled dip minus 4.7, pulsed plus 23, and a 46 per cent longer calculated cooling time on the dip case.

constructional standard with no additional accuracy claim, is permitted **plus or minus 10 per cent of the true value** on displayed current and voltage across the top three quarters of its range.[22] Ten per cent on current and ten on voltage compounds to roughly twenty per cent on the product, before you reach the waveform problem at all.

The third is the sensing point, which is the 4 v we already covered.

There's a procurement test for a clamp meter worth knowing. An acceptable instrument is often identified by the terms true energy, true power or power factor. One marked kVA, DC power or average power isn't acceptable. And for gas shielded metal arc the voltage should be sensed at the connection in the wire feeder, not at the power source.[23]

For the Person Signing the Purchase Order

The honest case for synergic control is variability reduction and faster changeover. It narrows the spread of parameters selected across a variable operator population, and it makes swapping between wire and gas combinations quicker.

They provide a good ‘setting’ starting point for a welder if they are set up properly and the welder has been trained on what synergic means and the pitfalls. That is worth the money and I wouldn't argue with it.

Two things that typically form the sales claims that deserve explanation, and both come from independent sources rather than manufacturers.

TWI surveyed its industrial and professional members on weld repair rates. Average 1 to 3 per cent in oil and gas and power, with peaks of 25 per cent at specific locations. The highest rates concentrate at root runs, fillet welds and areas of limited access. And the three dominant factors are **welder skill level, weld location and accessibility, and poor fit-up before welding**.[24] Read that against the sales proposition. Synergic control addresses none of the three.

The second is simpler. I went looking for independent quantification of synergic control's own contribution to productivity on manual GMAW, isolated from the pulse waveform or a consumable change, and I couldn't find any. Every figure in circulation is manufacturer sourced, and the headline one, three to four times the travel speed, is benchmarked against stick and TIG rather than the CV machines the buyer already owns.

There's a documented case worth knowing about before you spend the money. A fabricator with 250 welders and a yard full of different machines set out to move to synergic pulse. It went wrong in three places, and none of it was the welding.

The machines didn't match, so with two different brands, three generations on the floor and no two models sharing pulse programs they couldn't write one procedure that worked on all of them.

The leads and clamps weren't up to it either, and fixing that was money nobody had thought of or budgeted, because a poor connection warms up and a pulse machine reads the arc through that connection.

Good machines, crap filler wire, bad copper connections, poor welds. And the suppliers wouldn't say what was inside the programs, so the quality department couldn't write down what the machine was actually doing, and what you can't write down you can't qualify.

The shop went back to CV wherever it could as the technology wasn't understood and the change wasn't managed. Nobody had asked the first question, which their ‘key welding person’ eventually put to the supplier: what are you making that needs pulsing, when standard CV has been doing it for years?

What turned it around had nothing to do with the equipment. Trials on a few machines, a narrow set of settings that suited the work, then locked down. Training on the actual machines the crew would use. And the target set as making the machine run properly and producing the right size weld, not making it faster with black magic.

So be clear about what you've bought. The starting point is real, and good equipment is worth having. BUT good equipment will not instantly translate to faster, better welds. Nothing in the synergic curve fixes poor fit-up, access, substandard welding consumables or a welder who was never taught.

[22] EN 50504:2008, Validation of arc welding equipment, clause 4 table 1. Standard grade power sources: current and voltage within plus or minus 10 per cent of the true value between 100 and 25 per cent of the maximum setting.

[23] ISO/TR 18491:2026, clauses 6 and 7.4.

[24] TWI, Repair statistics of manufacturing and fabrication welding. Survey of industrial and professional members.

Budget for the change, not just the hardware. Ensure they are set up properly and you get the right wire and gas.

Train the welders on what synergic does, what it does not and what some of the likely issues are. Sort out the leads, clamps and work return when the machines are commissioned, because volts lost on the way to the arc come straight out of your welds. And check what the displays are telling you.

Do none of that and the new gear creates more problems than it solves and you will be disappointed.

That's what good change management and process optimisation looks like. This is the competence we need to develop in our industry. So do not buy synergic machines and expect a solution, unfortunately it is not written into the curves.

What to Do With This

For the welder:

Understand your equipment, read the manual then take a picture of the settings and then mess around with all the different knobs and functions. Just make sure you can get back to the original setting.

There's no better way to learn about a machine's functionality than to experience it. Your primary knob (amps, WFS, material thickness) picks a point on the curve, your trim is the quarter turn to tweak it to allow for variation, and your stick-out is the one thing on the procedure sheet you can control without a meter. So control it.

For the supervisor: record the trim setting next to current across the fleet of machines, check the program against what is physically loaded before you check anything else, and use manual CV as your isolation test.

Know the machine better than anyone in a workshop. Make it your business to understand the functionality, the ins and outs of the settings, what everything does. Ensure the wire feeders are displaying accurate values, and if they're not, make sure you've got an offset sticker so the welders know how far out they are.

Ultimately you're the one responsible for welding control. If you don't understand the machines and you can't dial them in to run properly, how is it that you're controlling the process?

For anyone writing procedures: record the amps, volts correctly with the right type of good quality tong tester, verify the travel speed, guesstimate the stick-out, and document the transfer mode in words. List the gas composition and trade name, the power source make, model if using pulse, the program identifier, which is the waveform, and ensure you have accurate values.

AS/NZS 1554.1 names synergic control once, in a note to clause 1.1, and it only adds to the confusion. A procedure that records only the machine settings has its range of application limited to equipment of that particular type, and it does not allow repeatable replication of what is at the arc.

For the owner: buy synergic machines at changeover time, understand what you are purchasing, resource the setup and get someone who knows the pitfalls of the technology. Get educated on ‘what good looks like’, ensure consistency across a variable crew.

Resource the implementation, ensure your key people ‘know the machine’, the equipment is set up properly and the welders are trained on the interface.

Don't buy it expecting it to fix fusion, access or fit-up, because those are the three things that drive your repair rate and none of them are in the curve.

There's a live version of every curve in this article at *grahamfry.com.au/technical-resources/synergic-mig-welding*, where you can pick a wire, a gas and a diameter, load the wrong program on purpose, and watch what it costs you.

> *The curve is a promise made in perfect conditions. Understanding what causes the variation, and what makes the displayed values inaccurate, is what lets you repeat the weld.*