Technical Discussion Paper

The Art of Weld Monitoring

This technical discussion paper aims to subjectively explain and discuss some technically detailed aspects associated with Weld Monitoring. The paper is designed to broadly help and inform Welding Engineers, Production Engineers and Quality Engineers about welding equipment measurements and weld monitoring methods.

The discussion is a little technical, gradually increasing in depth as the paper progresses. Further in, the paper explores the principles behind more sophisticated welding equipment and weld monitoring methods, their strengths and weaknesses, and how these principles might be applied to production process control.

In order to present the information, the paper discusses the potential benefits in using a Weld Monitor as the means to transfer a welding process from one welding station to another with minimal disruption.
In order to fully understand this methodology, it is necessary to look in detail at how the associated equipment broadly functions in order to tease out the detail that can ultimately affect the outcome.

Introduction

If you want to hit a target, it's always a good idea to know what you are aiming for.

It's equally sensible to know the capability of the equipment you're shooting with.
As Dirty Harry once said, "A man's got to know his limitations"!

If your target is moving, you're going to need to make judgements or measurements to determine the direction and speed of the target. If you are moving and the target is stationary, you need to know where you're heading and at what speed.

It therefore follows that if both you and the target are moving, you have your work cut out.

This simple analogy applies very well to the art of Weld Monitoring and subsequent production process control. The world of micro welding and associated equipment is full of technical specifications, but what do they really mean?

In much the same way as a car manufacturer publishes figures on the m.p.g., 0-60 time, top speed and green credentials as a technical benchmark for their offering, the discerning buyer and driver may want to dig deeper into the actual performance by taking a test drive.

Ultimately, whatever the final purchase decision is, you end up with a machine that will get you from A to B. If your target requirement is to simply get from A to B in a car, then practically any car will do, so the technical specs don't have much relevance.

This same analogy might be considered and applied to welding equipment and monitoring devices.

Probably the most basic form of a micro spot welding power supply is a capacitive discharge (CD) machine. For many applications, when setup and used correctly, these machines are capable of achieving some superbly consistent welding in highly controlled process environments. Simple and effective and like a basic car, there is also less to go wrong or understand when it's time for a service.

In other applications, these basic machines simply can't do the job, so other technologies such as servo based Linear machines, closed loop inverter machines and so on, have been created. As each different technology is applied, a new set of constraints and limitations will be associated and as such, these will have a bearing on the effectiveness of any weld monitoring that might be applied.

Technical Paper

The Art of Weld Monitoring

Q. Do you really get, what you set ?

Ideally, you might like to think that given two identical spot welding configurations; that is two identical power supplies, identical weld heads, electrodes and cables, that a welding process setup on one configuration would be entirely replicated on the other, if the settings on the power supply are the same and the welding forces are set the same.

So the answer is YES… BUT you would need to have identical equipment !!
The reality is not quite so : The welding equipment, like cars, will have operational limitations and tolerances.

Herein lies a fundamental principle behind the benefits of independent weld checking and monitoring.
Weld monitoring should serve as an independent checker for all those bits of kit that make up the welding configuration because they are almost never totally identical.
Furthermore, over time these bits of kit drift and wear and without detection, and so might your welding process and subsequent production output.

Unless the kit is brand new, never been used and fully calibrated, how do you know if anything has changed ?

Answer : You don't, unless you use a weld monitor and/or calibrate and set things continuously. Even then, if your weld monitor and/or calibration is unable to properly discern a difference or problem, you still won't know what if anything has changed.

Weld Heads

Normally you might rely on regular weld force setting checks pre-shift, but then again, do those daily weld head checks include proper checking for any bearing wear, copper flexure wear, tightness of connections etc… The heads might be fully automatic and servo controlled, but is the load cell working properly ? Even during a production run, connection joints can get hot and break without being noticed, springs can break, things can come loose.

All of these things can and will affect the welding and they may or may not go unnoticed without a weld monitor in place.

Welding Stations

As a basic starting point, Fig 1 shows a simple schematic of a simplified capacitive discharge (C.D) setup, indicating some of the variable electrical parameters in play, both in the weld head and the power supply.

Whether the power supply is a simple CD welder or a sophisticated closed loop controlled machine, questions might be, **Is it calibrated, is it still within calibration and what's happening at the weld ?**

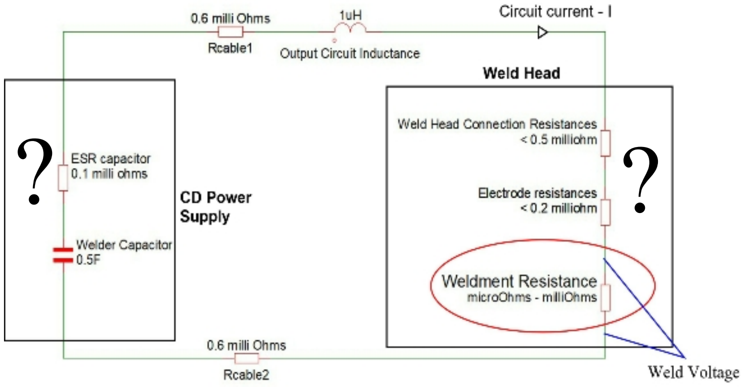


Fig 1

A weld monitor that works well should provide real time weld monitoring that will "keep an eye" on the entire set of welding equipment and thus can be constructively used to determine intervention, service and calibration intervals.

The benefits of transferring weld schedules with a weld monitor

Moving the weld schedule with a weld monitor

In normal production environments it is unlikely that all the equipment will be absolutely identical. It therefore stands to reason, that to replicate a welding process on "similar" equipment requires some means of referencing the ideal process setup at one machine and then to reference and transfer this machine setup to another.

This is where real time weld monitoring measurements can provide a real benefit. Rather than being overly concerned that no two power supply setups have exactly the same setting for the same weld process, the more relevant process indicative question is, **Are they delivering the same electrical payload to the weld ?**

Is control the solution ?

While more sophisticated servo controlled power supplies offer the advantage of controlling both timing and one of the machine output variables (Current, Voltage or Power), it is not unusual to find fully optimised high quality mass manufacturing lines running slightly different settings on "the same" equipment in order to make exactly the same joint.

In such cases, the actual weld energy payload is often used to monitor the process and indeed, allow for slight dynamic setting changes to accommodate such things as electrode burn in and wear that naturally occur over time.
Remember : The weld quality is the most important thing, so all you really want from your welding equipment is consistency with a precision reference to a good weld.

If the welder is 1% down on calibration, then does it really matter if you turn the setting up by 1% to compensate? If the cabling is slightly different and/or the weld head has slightly different follow up characteristics due to bearing wear, then that absolute 1% measurement doesn't really mean that much.

Furthermore, without a monitor in place, who is to know that it hasn't drifted to a 5% error the very next day?

Perfectly good welding processes running without control

With simple CD micro welding systems, be they micro resistance joints or micro arc welds derived from capacitor discharge, the welding current, voltage and hence power and energy depend very much upon the other electrical parameters in the circuit. (See Application notes 1 & 2 for more details).

This implies that in order to get the same welding result, you need to be entirely consistent with all the other process variables, such as materials, positioning, welding force and electrical circuit resistances and inductances. (*With micro arc welding, the arc gap, gas flow and electrode shape are critical*). The reality is, you can come close in matching these things, but it's only by measuring and monitoring the result at the weld, that you can be confident that the process is as close as possible to being the same from one machine setup to another.

Given the wide and variable tolerance nature of capacitors, even with a consistent and calibrated regulating control voltage, their absolute stored energy **will** differ from machine to machine. These variances also change over time and with temperature. Hence the W/S output setting is often very much a guide.

Furthermore, the energy actually delivered to the weld will vary considerably as a consequence of small differences in cabling and weld head resistances. It's little wonder then, many identical welds, on "identical" equipment sets require slightly different settings at the machine. So what is really going on ?

The benefits of transferring weld schedules with a weld monitor

What might you need to check and verifying a process has been replicated ?

As we have seen, reliance on the welding power supply settings and a force measurement is by no means a definitive answer. Normally it often suffices to simply monitor the delivered weld energy as close as possible to the weldment as a means of checking for “process normal” conditions.

To do so, your weld monitor will require a current sensor and voltage sensing leads to the electrodes and the ability to discern a weld energy level as a reference for the process.

To be sure that the welder is behaving as it should, it is advisable to also make an initial setup check and record of the current signal waveform in order to verify that it follows the expected characteristics.

This is especially sensible for closed loop power supplies in order to check that the timed portions of the programmed waveforms are correct and as they should be. Bear in mind that it not just the waveform amplitude that could potentially vary with a closed loop supply, the timing will also need checking.

Also bear in mind, that the absolute calibrated accuracy and control capability of a closed loop power supply may potentially drift close to a desired process window. If we take one unit with a +1% tolerance and another with a -1% tolerance, we’re starting with a 2% process transfer difference.

The same timing measurement considerations should also apply to CD welders that have the facility to modify the pulse shape; thereby ensuring checks are like for like across similar weld stations.

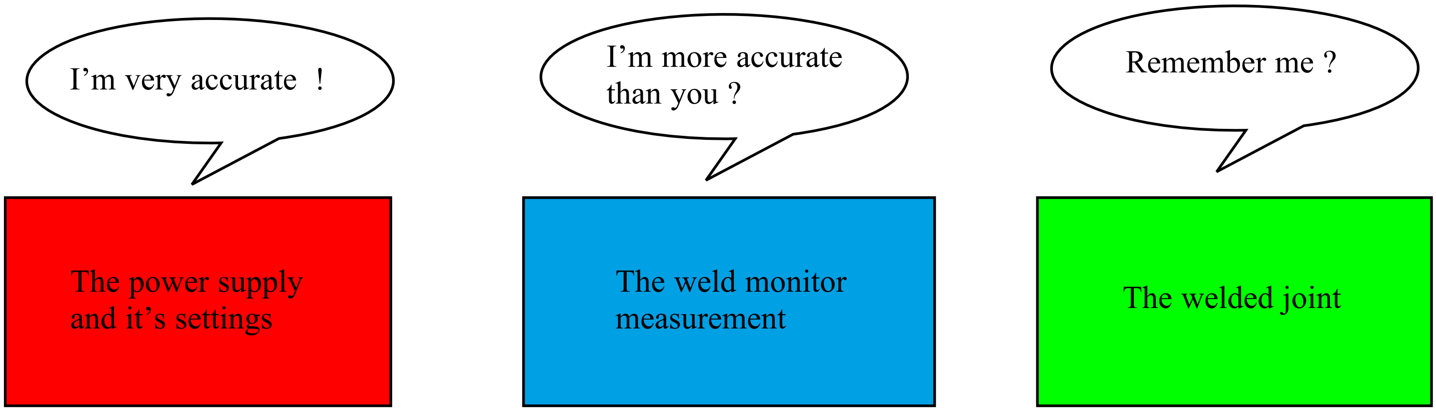
Once checked, the delivered weld energy should provide a highly process indicative reference and ideally, the monitor will be kept in situ in order to provide a continuous process check for production purposes.

Thus, by using some form of measurement or monitoring, reference settings taken from one machine can be transferred to another machine and then the equipment adjusted until the delivered weld energy payload falls within the same process window on all other machines doing the same job.

Remember : It’s actually O.K. to operate with slightly different welder settings at different stations for the same welded joint; just so long as you know the reasoning why.

So why do people “calibrate” their welders and then calibrate their weld monitors ?

This can be a tricky question to answer, given the above and becomes a bit lengthy and technical as we dig deeper. **So which one of the boxes below best defines the welding process ?**



The benefits of transferring weld schedules with a weld monitor

So why do people "calibrate" their welders and then calibrate their weld monitors ?

The most important thing to focus on, is the ideal weld process conditions, since **everyone** cares about the actual weld quality. How you get their and maintain this, is discussed further, but for now, the focus is on the ideal weld conditions.

In order to establish the ideal weld process, Design of Experiments (DoE) techniques, or as we say in the U.K., Welding Trials must be carried out. In a nut shell, this amounts to setting up laboratory conditions in which the welded joint is made using various welding equipment settings until such time as the welding engineer can statistically show that they have the best fit set of conditions.

In order to do this statistically, one process variable at a time is adjusted, a small sample of welds made, and then the welded samples are analysed for appearance and strength, usually using destructive methods such as peel and pull tests to verify target strengths. Average and standard deviation values for force, current, energy and pull strength then provide an indication of the process mean and variance levels around it.

The welding engineer is aiming to statistically evaluate the effect of each process variable (Force, current, waveform shape etc..) on both the joint and usually also upon the electrode life. As a broad and crude starting point, the engineer will want to minimise the overall energy put into the weld and minimise any potential sparking in order to achieve a particular weld strength. Excessive joint strength can be a sign of excessive energy, so sensible target values need to be pre-defined in order to minimise energy, localised heating and electrode wear.

The analysis should statistically show that the particular set up conditions sit in the middle of the parametric range of possible adjustments, such that small changes in any parameter have the least effect.

For fine wire welding and more complex material joints, this process is considerably more detailed, complex and lengthy, but the principle remains the same - **to define the ideal weld process conditions.**

Key point : The ideal welding conditions ARE the "calibrated" process reference point.

The most important thing to do once these conditions have been determined, is to properly and "accurately" record and reference the setup.

Hints & Tips

Having defined and recorded the ideal welding scenario, it's a very good idea to repeat the methodology to define some welding process limits and fault scenarios.

In other words, contrive conditions that constitute undesirable welding conditions and then take measurements to record the effect these have.

Simple examples would include component misplacement or misalignment, incorrectly adjusted force settings, incorrect electrode dimensions etc..

These measurements and records are especially sensible if you intend to use a weld monitor of any kind and at the very least, they provide process records that can be referred to quickly should the production process change.

If you intend using a weld monitor, then make sure that it is able to accurately discern the measurement differences needed to detect these undesirable conditions. If not, then don't use it and/or source another one !

The benefits of transferring weld schedules with a weld monitor

How might you capture and record a "calibrated" weld process setup ?

BE WARNED : This is where things get a bit more tricky and technical - so we'll start with a very basic scenario and then move on.

Say for example you have a straight forward "master" capacitive discharge machine serving as the basis for a welding trial, then **DO NOT** expect exactly the same results from any other machine of the same make and model, regardless of whether or not it has been "calibrated".

By definition and at the very least, there will always be very slight differences due to the capacitor tolerances and aging variations from machine to machine - hence, while you may record them, the output settings on the machine should be treated as a guide. Furthermore, the energy actually arriving at the weld is not the same as that dispensed at the output, since cabling and joints etc.. modify the final weld energy.

While many processes will be insensitive enough to tolerate these natural and relatively small machine setting differences, others won't and in either case, the best thing to do is to employ some **precision** measuring equipment in order to properly record the expected current waveform and total energy delivered to the weld.

So what is meant by precision ?

Well first you need an absolutely "accurate" current sensor ? (*Maybe ?*)

Check the specs and calibration, both for dynamic, static and absolute ranges. None insertion Hall effect devices are convenient but gain and offset characteristics need to be taken into account if you're seeking absolute accuracy.

Rogowski coils are good for a changing signal, but again, physical positioning, gain, offset and drift issues associated with the signal conditioning electronics need to be considered if seeking absolute accuracy.

Simple low insertion current shunts provide an accuracy defined, dynamically versatile and stable measurement, but often also require some precision signal amplification for measurements to be made.

Next, something to accurately measure the current waveform ? (*Maybe ?*)

For absolute accuracy the devil is in the detail, so if you choose to hook up a calibrated oscilloscope, make sure that it cost around the same price as a small car. When you look in detail at the absolute accuracy figures of oscilloscopes for say under £3000, you will find that range changes, gains, offsets and digital acquisition ranges often amount to less absolute accuracy than that of a humble current shunt !

That's not good if you want an "accurate" record of the process… Right ? (*Suggested answers come later*).

Instead of an oscilloscope, you might choose to buy or hire a weld monitoring device in order to capture the information; again, be aware that exactly the same absolute accuracy issues may or may not be applicable in what you are trying to achieve, especially through digital capture.

At the very least, consider how and when was the weld monitor calibrated ?
(Presumably with an expensive oscilloscope ?)

Sensor Accuracy ?	Measurement Accuracy ?	Equipment Accuracy ?

The benefits of transferring weld schedules with a weld monitor

How might you capture and record a "calibrated" weld process setup ?

Absolute accuracy in electronic measurements is all about accuracy budgets.

Rather like high quality audio systems or guitar pickups, the devil in the detail comes from using precision, low noise, appropriately filtered signal conditioning at the front end of the electronics in conjunction with an accurate and stable measurement transducer.

Thus, assuming you have dealt with and understood all of the above, you can now accurately record your reference waveforms, your measured energy at the weld and then all of the other parameters associated with the ideal weld. i.e. force settings, electrode details, cable lengths and layout, equipment setup, materials and photos etc… and those associated with errors and limit transgressions.

We're not there yet ….

The above walk through was for a basic capacitive discharge (CD) machine : A machine that produces a pure clean un-impaired electrical current signal.

If we now think about the next "purest" machine signal in micro spot welding, you'd likely plump for a purely Linear DC micro welding power supply.

The Linear DC micro spot welder will likely be a servo controlled power supply, allowing adjustments to be made to the waveform shape timings (up-slope, peak, down-slope) as well as the amplitude of the controlled variable i.e. Current, Voltage or Power.

These machines are typically chosen for their flexibility, accuracy and dynamic response, generally for currents below 1000A and are controlled by electronic servo loops, which depend on sensors.

Herein lies a new challenge : What is the accuracy of the servo loop control and how is that calibrated ?

Ever noticed a car cruise control reduce speed slightly when encountering a hill - that's servo error.

A servo loop by definition needs an error to work with and the amplitude of that error will change dynamically as the servo loop endeavours to compensate in making the output match the target.

In the case of a servo based linear micro welding power supply, the dynamics of the output will depend upon the demand output versus the load and the load dynamics.
In other words, a linear machine attempting to dynamically deliver 500A into a 1V load (2 milliohm) will very likely deliver a slightly different payload into a 3V load (6 milliohm). **That's servo error !!!**

So, if you've "calibrated" your ideal welding condition in the laboratory on your calibrated servo based Linear DC micro spot welding machine and then measured everything with your expensive calibrated weld monitor or oscilloscope, and have then attempted to move the process to the production line with an extra few metres of cabling or a slightly different connection at the weld head, then those few extra milliohms may well have modified your original welding process measurement "accuracy", or pushed it a bit towards a process limit.

Hence you would need to re-check or ideally monitor the actual process signals in the actual process, to be sure they match the original setup.

You may well find that you have to tweak your power supply settings slightly to suit the setup and to match the original ideal weld conditions !! That's why it's good to measure and monitor at the weld.

The benefits of transferring weld schedules with a weld monitor

How might you capture and record a "calibrated" weld process setup ?

What is the Closed loop control mode accuracy ?

Be they Linear or Inverter type power supplies, it is inevitable that the absolute accuracy and response capability will be modified by the type of operational mode chosen, i.e. Voltage, Current or Power.
This is an important point to consider when deciding on the best mode to operate with and when trying to calibrate and measure the machine mode performance.

These differences are not always clear from the technical specifications, simply because those specifications are normally written to reflect particular test conditions, as is the same with cars.

Fig 2

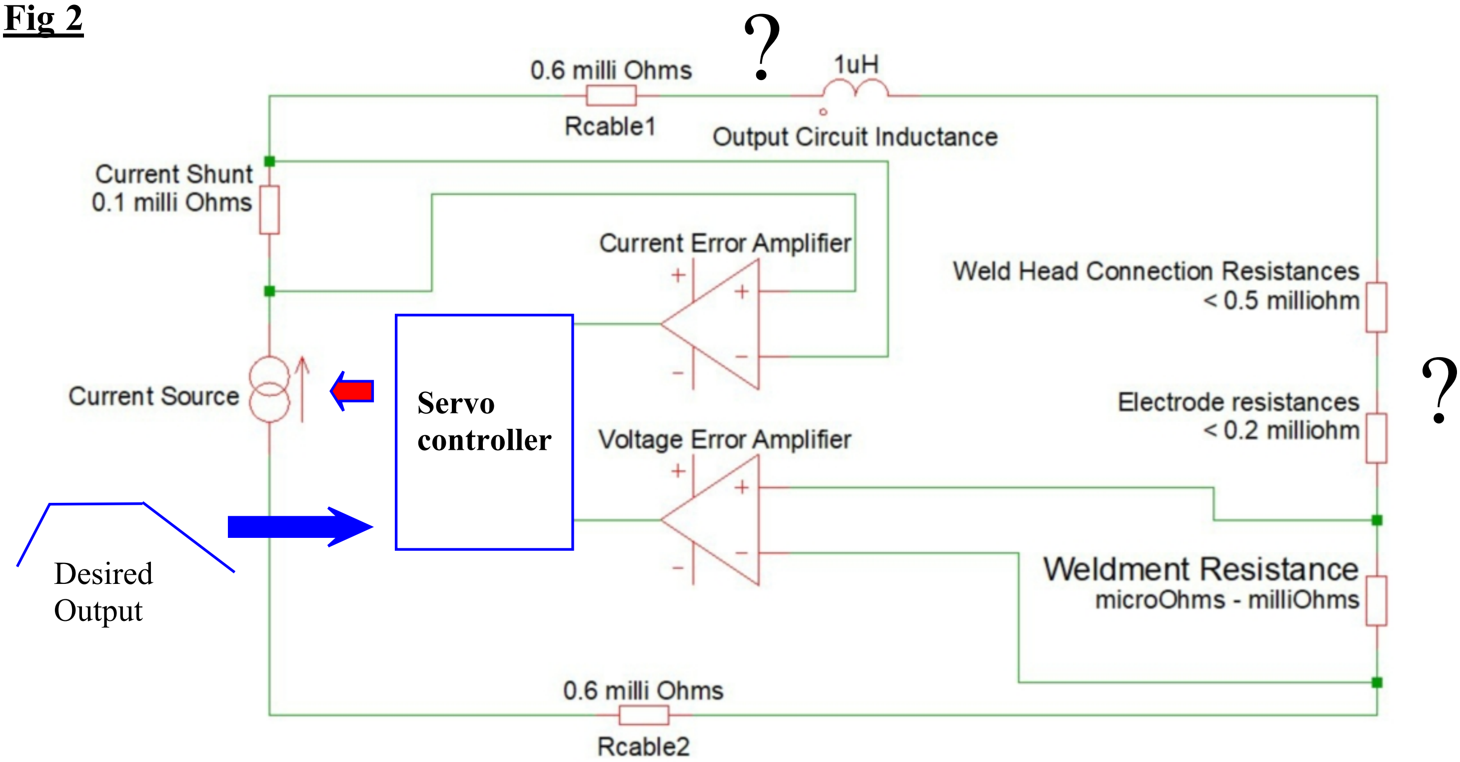


Fig 2 shows a simplified schematic in which a servo system is comparing a desired output waveform (left) with a choice of feedback signals in order to determine an error by which to drive the primary current source.

In the case of voltage feedback, it's important to note that the sensing points are at the welding electrodes, which in turn are electrically separated from the current source by cabling resistance, weld head resistance and inductance. As we will see again later with inverters, the presence of these parameters has a bearing on the ability of the control loop to accurately follow and maintain the target.

These differences are quite small, but nonetheless, they will vary with the circuit configuration, the welding load and the desired target waveform rate of change and level. They thus contribute to real and variable inaccuracies when endeavouring to define and measure absolute accuracy and/or transfer a welding process from one place to another.

Furthermore, the dynamic and absolute performance of these electronic servo systems can and will vary from machine type to machine type, so it is important to appreciate these nuances, when for example, choosing a replacement or upgraded machine for a particular process.

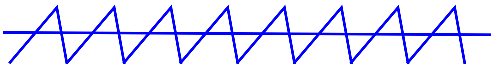
The benefits of transferring weld schedules with a weld monitor

How might you capture and record a "calibrated" weld process setup ?

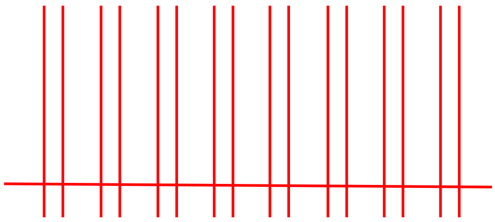
Still a bit more to consider with closed loop control mode accuracy ?

Assuming you still have a desire in trying to "accurately" measure your welding process and equipment, you may need to consider whether or not your micro welding power supply uses any "switched mode" technology.

Switched mode power control systems are used in inverter (sometimes called HFDC) power supplies. Hybrid supplies also include some switching. These topologies provide much greater efficiencies in power conversion but such advantages come at an accuracy vs measurement price and it is important to understand how this can impact upon process monitoring measurements.



Average measurement : 2000 Amps : Ripple +/- 10A



Average measurement : 0.5 Volts DC - Voltage spikes 0-10V

Switched mode systems "switch on & off" at high frequency so that the average output maintains a target value. At each switching transition, the output current varies slightly up and down (ripple) and voltage spikes occur due to circuit inductances as current levels transition as rise and fall ripple. The ripple is actually an inner servo loop making adjustments as it goes along. These natural transgressions "interfere" with absolute measurements and can be particularly erroneous in digital acquisition systems.

If we take for example a 10A ripple riding on a 2000A average, then in order to properly measure this data, we need at least a 12 bit calibrated digital resolution. That's a 4096 sampling range, with a minimal +/- 1 LSB accuracy, leaving just 2048 ADC samples to represent 2000A and that's without other associated digital errors. That's roughly 1 bit per amp attempting to accurately measure a signal with 20 bits of ripple.
That's 5% resolution around the underlying average current level

Taking the voltage signal, we see high speed noise spikes extending to 0-10V on a 0.5V average, so again digitisation performance can quickly become an accuracy issue. Depending on sampling speed, some voltage spikes might get measured while others might be missed.

Finally of course, if we're attempting to compute actual energy with these two signals, then digitally combining the signals also combines the errors, leaving greater uncertainty in the final result.

In order to better "view" or measure these signals, electronic filters are often applied in weld monitors and digital oscilloscopes. These filters help to remove unwanted "noise" from the measurement signal so that a more consistent measurement value can be obtained for display and reference purposes.

Depending upon the quality and frequency response definition, such filters can and will affect the absolute "calibration accuracy" of the dynamic and static measurements made.

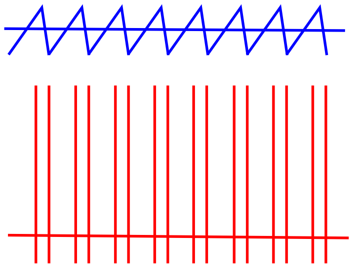
It is therefore important to understand what, if any, filtering has been applied during a weld process measurement definition and to make sure that exactly the same filtering is used when attempting to monitor the welding process in production or when moving the process to other equipment.

The benefits of transferring weld schedules with a weld monitor

How might you capture and record a "calibrated" weld process setup ?

Noise annoys

As a further consequence of ripple currents and switching noise, switched mode power supplies need to internally employ filtering within their servo loops so that they derive some kind of measurement indicative of the mean voltage and current.



Such filters inherently have an effect on the frequency response of the servo system, which explains why switched mode inverter power supplies are not as dynamically responsive as their "cleaner" Linear based counterparts.

As you might also expect, the relative ripple level amplitudes and switching noise will vary with load, thereby varying the ultimate target achieved by the servo loop; thereby affecting the actual output level; thereby affecting the apparent calibration.

Hence the real world importance of fully understanding what is trying to be measured and how.

In the case of an inverter machine attempting to operate in voltage control, it is clear that if measurements happen to pick out some of the voltage spikes, then the average value measured will be hugely skewed.

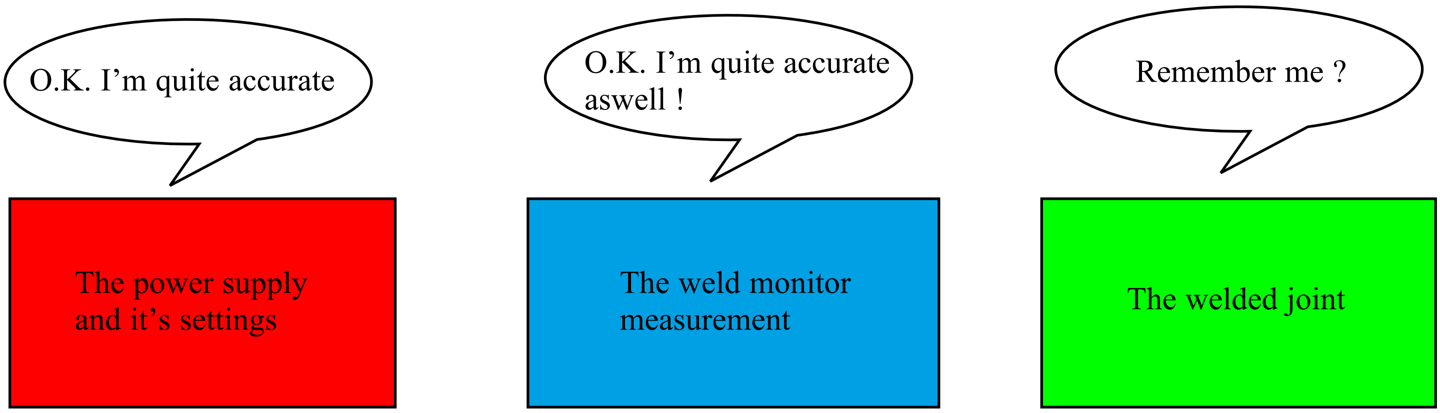
High quality and selective filtering is needed to reduce this inaccuracy to a minimum. Trade offs have to be reached between power supply dynamic performance and output accuracy. This is why an inverter power supply will tend to be more dynamic in current control rather than when in voltage or power control.

Exactly the same principles apply when attempting to take a measurement with a weld monitor or an oscilloscope.

Decent digital oscilloscopes will have built in filtering functions, which will usually be required when attempting to measure the voltage signal from an inverter based system.

By selecting different levels of filtering, you will find the average measured value will change.
This poses an obvious problem for both the calibration of the equipment and the calibration of the weld monitor.

How do you know the filtering is doing the same job in both bits of kit ?



The benefits of transferring weld schedules with a weld monitor

Taking Absolute S.I. Unit calibration with a pinch of salt

So where is the accuracy Holy Grail ? ***(See U.K., Monty Python and King Arthur for more details)***

Q. Why do many excellent recipes include a "pinch of salt" ?

What sort of absolute S.I. measurement is a pinch of salt ? and yet, the world over, we kind of know what this means, even though it must differ from chef to chef…

We also know, that "taken with a pinch of salt" means, not to take something too seriously.

Both analogies apply equally well to the Art of Weld Monitoring. Many hundreds of hours have been spent by seriously good quality engineers, calibration engineers and welding engineers debating how they might all prove beyond doubt that they have 100% measurement traceability and a defined S.I. measurement accuracy for their welding process, especially for the electrical definition.

Hopefully by now, you can see why this process of debate in welding might be taken with a "pinch of salt" in a lot of circumstances, as a consequence of the potential errors and tolerances throughout the kit.

At the same time, a "pinch of salt" might very well define whether or not the chef's recipe makes the Michelin grade. When making the perfect recipe, time after time, the chef is attempting to achieve high quality, which is to say, high consistency in replicating that which is deemed to be good. The ingredient measurement system used is often difficult to absolutely define, especially in S.I. Units.

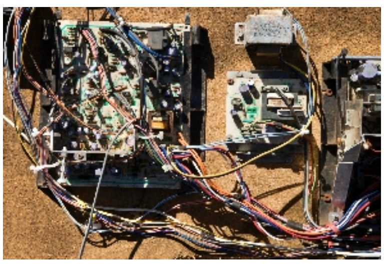
This is the same principle the welding engineer is using to define the ideal welding process with the initial welding equipment trials. This is where the process calibration standard must be defined - the welded joint.

This is the chef's starting point - The ideal recipe made with some kitchen equipment.
Same as, - The ideal weld made with some welding equipment.

So, in order to make a Big Mac™ in New York taste the same as one in Shanghai, all you need to do is take a precise note of the ingredients, equipment used and the cooking process applied.
The only **absolute** requirement is to make sure that the "measurements" and recorded definition of the process, remain the same as those used to define the original tasty BigMac™.

What this potentially means is that if the welding engineer has taken their original current trace and weld energy measurements on a **£100** oscilloscope **AND** they are aware of the "absolute" accuracy issues in what they are using and measuring, then what they have done, is to **define a process** by which the ideal weld information could be transferred from one to place to another, simply by moving the oscilloscope.

They can get from A to B simply by using the same measuring equipment and method.



The benefits of transferring weld schedules with a weld monitor

Keeping things simple often amounts to clarifying what you really want.

Decisions to seek the Holy Grail should not be taken lightly.

The Knights of Old, British comedy and Legends, all warn us that the search for the Holy Grail can be full of difficulty and danger, with unanticipated surprises lurking at every turn.

That is the ABSOLUTE truth… ***or please prove otherwise.***

The important point about absolute measurement accuracy in welding, is that it's practically impossible to be absolutely precise.

It is therefore perhaps better to quantify and consider the overall accuracy budget that a particular system can realistically achieve, before deciding how best to measure and record it.

If, given the sum of sensor errors, servo errors, load and layout errors etc.. an overall absolute system accuracy is more than 5% out in the worst case, then do you really need a better than 1% measurement and does that measurement really need to be an ABSOLUTE one ?

Calibration Standards

If you're still following this and haven't nipped out in pursuit of the Holy Grail, then you will very likely know that practically all equipment calibration infers some kind of traceability.

A measurement standard (like the perfect Ampere), is held somewhere special and acts as a reference point to an S.I. Unit. Test house calibration equipment is referenced back to the standard, as are subsequent equipment calibrations made by the test house. Thus we get Traceable Standards to which Quality people can obtain labels and certificates to stick on machines and file.

The problem often arises in proving something is calibrated properly and this is particularly so with micro spot welding equipment and associated accessories.

In highly controlled, highly accurate welding setup conditions, the ability to have such a close reference back to the S.I. control standard can be important and comforting. It may also actually be achievable.

The welding equipment doesn't need to be highly sophisticated, it could simply be a CD machine that has to be adjusted very finely and to prove that, a fine process measurement is needed and indeed is possible. Hence in this example, we are choosing an S.I. Unit gold standard reference.

Once setup and working, the equipment itself could in itself, be considered the "local standard".
So now we could choose to reference all similar machine setups back to this single "local standard".

Having done so, we have now created another "local standard" with the addition of some potential measurement error coming from whatever measuring or monitoring equipment we have used to check back to our gold standard machine setup.

So if we know the Gold Standard machine is working fine and we can tolerate a 1% accuracy process transfer error, there is every chance we can use a **£100 oscilloscope** to do so !!

The benefits of transferring weld schedules with a weld monitor

Keeping things simple often amounts to clarifying what you really want.

Successful process transfer from one welding setup to another is one area in which a weld monitor can add some real value.
The term "weld checker" is the same thing and perhaps better describes the desired function of the monitor, which is to say, it can successfully "check" the welding process; and as we have seen, there are many ways to go about this !

Monitoring a process infers taking regular "check" measurements to be sure all is well. Clearly, it is ideal if you can check every single weld, but of course that implies the need to have a Weld Monitor in permanent place at each welding station. That's a question of quality, cost, capability and conscience.

If a process transgression is detected, it is desirable of course that the weld monitor indicates this externally, allowing the process transgression to be investigated and/or product rejected.

Weld Monitoring can also include weld data logging, whereby weld measurements are recorded at each and every weld, time-stamped and stored.

The value of mass data storage

Quality biased professionals typically like to say and prove they have accurate, traceable records of just about everything and for some, the attraction of gathering and storing as much data as possible can be a key driver in their quality assurance strategy. Better to have too much than too little, right ?

In terms of efficient value add, the accountants out there might be saying, well just store what is necessary and useful; save time, effort and money. This leads to the question :
What value is there in mass data storage ?

One way to consider the question, is to consider the actual value of the data. We know there are limitations in defining absolute S.I. measurements but we also know that if we are consistent in what we do and measure, then we have some valuable process data.

One potential use for some limited data storage capability is that in deriving Statistical Process Control (SPC) values that determine the upper and lower limits of the process. Collecting this data in real time allows us to watch in real time, where statistically the process seems to be sitting.
From this, we can see Live statistical trends on graphs and bar charts.. if of course, we really want to !

Having said that, ideally the process operational boundaries will have already been established during the initial welding trials and if the weld monitoring system is doing it's job properly, it will simply start to flag Upper or Lower process limit transgressions during the course of production.

These limit transgressions don't necessarily need to be "Faults" as such, they can simply be set up to flag that an intervention is required, for example, it might be time to clean the electrodes.

With confidence in the initial statistical welding trial data, this Gold Standard for statistical process limits should form the basis for the SPC intervention points, hence the need to record every piece of data on every weld that falls in between, might be seen as questionable in terms of value add.
As usual, much depends upon what you are really aiming to achieve…

The benefits of transferring weld schedules with a weld monitor

The value of mass data storage

Small scale data collection and SPC analysis can be a useful tool for the welding engineer in honing a Gold standard for process limits. Having defined and tested the ideal welding conditions in the laboratory or on the gold standard machine, the welding engineer will recognise the benefits in further measuring and testing these conditions in the real production arena over larger numbers of product, in order to improve the statistical certainties and knowledge base.

Compared with oscilloscopes, Weld monitors with data acquisition ports and facilities provide an excellent interface to the welding parameters for the welding engineer. So long as the equipment types and measurement methods remain consistent to those used in the initial trials, the welding engineer can effectively extend the welding trial to production for a while.

There must however come a point where the welding trial information is considered sufficient as to be declared correct and useable. So again, why might you want to continue to collect masses of data ?

What can you rely on ?

If you are relying on a weld monitor to detect process boundaries, then of course, you must prove it will do this. As mentioned, this should form part of a welding trial (DoE) and simply means proving that the monitor will flag the things you want it to flag, so that manual or automatic intervention can take place.

In taking this approach, care must be taken when or if external interventions take place, such as an external "calibration" of the equipment. Many a calibrated power supply has gone back on line, only to need different settings, while others have stayed on-line and considered in calibration for 15 years ! **Go figure…**

It is also important to keep in mind the process definition made by the original welding engineer. It's no use using a weld monitor for determining welding trial parameters and then leaving the monitor on a production line, only to be tampered with by production operatives or production engineers.

<u>So, hide it away, lock it in a box and/or password protect the weld monitor… Right ??</u>

Yes and maybe : But of course, you also have to do exactly the same for the power supply controls, the force control on the weld head, while also making sure that the material supply chain hasn't changed, the electrodes are correct, all the system joints are perfectly made etc… otherwise the monitoring setup and purpose is invalidated anyway !

Can you trust your people ?

Why is it that most Production Engineers have access to all the equipment supervisor passwords ?? It's the same in some of the most highly controlled environments !

Let's face it, it's because it's their job to maintain production output, but can they be trusted ? There again, can you trust the welding and measuring equipment more so ?

Herein lies another problem, the known process drift.. so how might you deal with that?

Does the welder output change a bit over time ?
Does the monitor measurement change a bit over time ?

The benefits of transferring weld schedules with a weld monitor

The value of mass data storage

A triage of trust

The point in using any weld monitor is to keep an eye on the process and to flag up potential problems.
If you can totally trust all of the other welding equipment in play to provide a consistent result each and every time, then you shouldn't need a weld monitor.

If your weld monitor is built into the welding power supply, can you trust it ? What happens if the power supply starts to drift or fail, will the monitor do the same ? How can you ever be sure ?

Alternatively, you might place trust in your trained welding operatives to keep the process on track. These choices are all subjective and highly dependent upon the environment and the way in which you operate.

If you have decided that an external weld monitor will improve your faith in the process, then there is no point in having one, unless you trust it and to do so, you must prove it detects the things you want it to detect. If you have proven that, then you have some basis of trust.

In trusting a weld monitor, you must then trust your people (or automation) to act upon it's advice !
In other words, have someone trained that understands the equipment and process and who knows what to do when a process limit is flagged. This might be something as simple as cleaning the electrodes, or in the case where equipment is known to drift over time, allow them to adjust the equipment slightly to get things back on track.

If you really trust your people and know your process well, you may have found that your process limits can and should be adjusted slightly over time to accommodate other known or learned factors, such as gradual electrode life change, slight material batch changes etc..

In these cases, the production engineer may have learned that the equipment settings should remain the same, but the process limits should be adjusted slightly to accommodate other learned factors.

The extent to which this is allowed is entirely a matter of pragmatic choice and trust.
The degree of trust and extent in allowing equipment adjustments to be made should be defined as part of the quality control process. Adjustments are often necessary, they simply need to be controlled.

Trusting mass data collection ?

Track & Trace has become a new phrase with Covid-19. People struggle to trust other people and sometimes for good reason.

Mass data collection is often far more to do with "what happened, and/or who did what and when", so that when a post manufacturing problem is raised, someone in Quality Control can look up records to show as much data about the questionable event as possible.

Whether that data is actually useful or valid is often a moot point, since you don't know what you don't know ?

But that's internationally known as "Traceability" nonetheless.

The benefits of transferring weld schedules with a weld monitor

The value of mass data storage - can you trust the data ?

We can all think of product recalls made by reputable manufacturers operating to strict quality assurance programs. As with Absolute accuracy calibration records, these manufacturers will all have subscribed to corporate policies, processes and wall certificates that demonstrate their genuine commitment to these things.

And yet, and as we all know, mistakes still occasionally happen giving rise to the commonly overused statement and phrase - "lessons have been learned" ?

Whether it be a welding process or a food manufacturing process, the chances are there will have been some form of process monitoring, data collection and SPC limits and quality standards associated with it - and yet, occasionally a product recall becomes necessary.

Aerospace is one industry that defines additional quality standards (AS9100) that seek to always determine the "root cause of a problem" if things go wrong and to further document and action any corrective action to an extent that it is truly corrected as far as is practically possible.

In the first instance of a potential recall, (*usually one of shock, horror, disbelief and defence*), there will be a scramble to see what data records are available to show that every machine and every human did their jobs properly at the time of manufacture. In other words, the hunt is on to find out where the problem originated and "who" is really responsible.

This common, natural human instinct and process could be seen as slightly ironic since for the most part, the manufacturer had previously felt safely cocooned in their highly honed quality system and fully vetted supply chain; a false sense of security perhaps ?

In other words, they will have put in place what they consider to be a robust quality manufacturing system but perhaps may have taken their "eye off the target" as a consequence.

Continuous improvement, six-sigma methodologies and the like, are all aimed at improving things...

For these commendable systems to be truly effective, you must of course be very sure you know what an improvement really is !

Getting back to the mass data storage and welding

If your Weld Monitoring system and SPC setup was perfect, then there would be little need to record very much data.

A. You would know for sure, that nothing bad would get past it… Right ?

B. If that is not the case, then you can't fully trust it… Right ?

C. If you can't fully trust it, then what value weighting do you place on it's ability to acquire and store useful data ?

D. If you have made 20,000 welded joints and recorded the current trace for each and every one, who wants to review them, especially if you're not sure the traces carry very much real world value; After all your monitoring has already passed them !

The benefits of transferring weld schedules with a weld monitor

The value of mass data storage - can you trust the data ?

Big Brother is watching and as always, a lot comes down to trust.

One possible use for mass weld trace data storage, post traumatic quality event, is to go back to see what all the machine settings were, who was the Production Engineer, what time the weld happened, was the kit in calibration and can that *(really)* be proven, and so on….

At this point, the quality system is already creaking, because now you have trust issues over whether or not, someone did something they shouldn't have, or perhaps something somewhere failed temporarily.

In either case, you are now questioning your ability to enforce your own quality defined gold standard welding process as well as your ability to properly monitor it, either by machine or by person.

Maybe the potential welding fault from 20,000 welds ago was caused by a parameter that wasn't being monitored ? How would you know that ?

If you have implemented full current trace logging for every single weld in your production process, you should be able to find the trace, that made the weld, that passed through the monitor.. So now what ?

The chances are, the trace will look fine, because the monitor checked it through at the time it was made.

If it doesn't, you have just learned how to monitor properly when setting up a welding process !

That would of course, then casts serious doubts over the other 19,999 welds, that may or may not now been deemed as potentially problematic.
In addition, the welding engineer that did the original trial (DoE) is no where to be found.

Why not trust the humans to NOT trust the machines - wasn't that human nature once ? *(I'll be back!)*

It might been seen as a little old fashioned in mass automated production lines these days, but the very act of actually physically sampling some of the output and carrying out batch pull & peel tests, is a very good way to ensure quality.

Yes, we're talking about physical human inspections, made to be part of the production process !!!

It takes a bit more time, it costs a bit more money, but it can have big advantages.
At the very least, such methods can be seen rather like a "batch based, dual redundancy system".

Checkers, that occasionally check the checkers, so to speak…

If a batch welding problem has been detected at this inspection point, you have isolated both the batch and isolated a problem with your welding process, monitoring system and equipment.

Furthermore, you will now know something that you didn't know before.

Calibrate your equipment as best you can when aiming for a target.

Mark Aherne