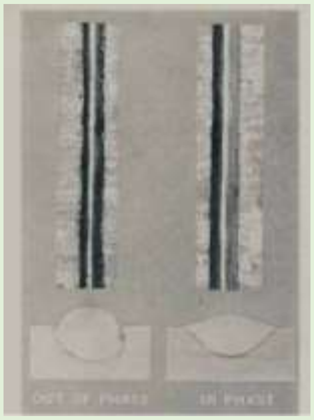
WA Technology

Welding
Accessories
Technology

Arc Deflection/Multiwire Arc Interaction Effects SAW Quality

My first published technical paper summarized a several year research effort at increasing the welding speeds of the multiwire Submerged Arc Welding (SAW) process used to manufacture large diameter gas and oil transmission pipe. This was a significant development since it provided 65% productivity increases and cost saving for the many pipemills that employed the system. It also was instrumental in maintaining an exclusive supply position for my company for submerged arc flux and wire in the nine UOE US and Canadian pipemills. This was a significant volume business in the 1960 thru early 1980's when most of the gas and oil transmission pipe was installed in North America.

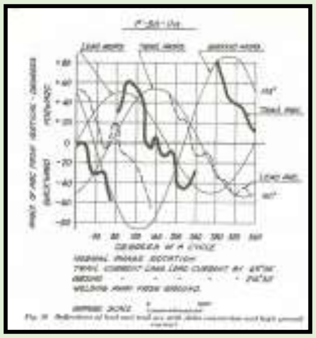
Arc Deflection; Key to Success



The technccal paper, published in June 1968 in the American Welding Societies, Welding Journal is entitled "Three Wire Submerged Arc Welding of Line Pipe." It presents research information showing that the all AC power system phasing had a major influence on the final weld profile. The photo upper left is from the paper and shows that with the exact same welding parameters a properly phased system made a well-shaped deposit where with the phasing reversed the weld is humped and undercut! This review discusses the process development and the significance of the resulting production advantages. It is provided to show what many have forgotten or never knew about this very important process parameter. Also provided are several sidebars that review submerged arc welding process development and some of the early pioneers who advanced the use of the process. *Sidebars are in Blue italic type.*

History of Multiwire SAW

The influence of arc deflection on weld quality was known for some time prior to our mid 1960's research. A June 1952 AWS Welding Journal paper by Clapp and Schreiner entitled "Characteristics of Submerged Arc Welding with Three-Phase Power," studied the weld quality with various phase angles with two wire AC AC welding. They used a technique also employed in our work, which was to have the multiwire system operate without flux and employ high speed photography to film the arc interaction. Although the angular deflection magnitude is different in air then when under flux, the direction and relative magnitude provides a valid qualitative analysis. Clapp and Schreiner, as did we, examined the film, frame by frame. I distinctly recall the considerable time it took to accomplish this task and view enough cycles to get a statistically relevant average. The figure upper right shows arc deflection recorded by Clapp and Schreiner.



Sidebar-SAW History

There are a number of erroneous references siting patent by Robinoff, filed in 1929 as the invention of SAW; in fact it is not! Perhaps the best source to dispel that idea is the patent teaching of the real first SAW patent by Kennedy at all, assigned to the Linde Division of UCC in 1935. Linde also purchased the patent rights to the Robinoff patents to have full protection. But the Kennedy patent, in which the arc was truly submerged, had no other patent citations listed. In addition, it describes what is no doubt the Robinoff patented process as requiring the wearing of gas masks as the arc was only partially submerged and the flux incorporated iron oxide to magnetically attract the flux to the wire! Suggest going to the following page on our website for an accurate SAW history with quality references:

http://netwelding.com/History_Submerged_Arc%201.htm

Of Interest, Kennedy was hired by a US Steel company making gas and oil transmission line pipe to improve the weld quality of the Robinoff process. When there was a disagreement between Kennedy and the US Steel company, Linde purchased his patents!

Several people were a major help in my early career working with SAW. One was Norm Schreiner who started with Union Carbide during the depression in 1935. He worked on the then newly introduced and proprietary process that was called Unionmelt, a contraction of Union Carbide and the Submerged Arc flux; called "Melt." This melt or flux was produced by UCC's Metals Division in a large Ferro Alloy electric furnaces and sold to Linde. Though 1949, Linde received a $0.05 per pound of weld metal deposited royalty from fabricators using the process. Of interest, there was a major patent suit between Union Carbide and Lincoln Electric regarding SAW that went all the way up to the Supreme Court. In the 1949 verdict Lincoln could no longer make the fused flux that they were selling but the basic process patent was not upheld. In the history referenced above you can see the letters sent by Lincoln and Linde to customers. Linde stopped charging a royalty but raised flux prices to compensate. At the time prices for flux from both companies were similar. Lincoln went on to develop bonded fluxes since they could no longer sell fused flux. Linde continued to only sell fused flux until the early 1970's.

Norm Schreiner was a brilliant engineer and rose to the title of VP Unionmelt. When I joined Linde (now renamed Praxair) R&D in the mid '60's, Norm was the key contact with all of the North American main line pipemills. He brought me to meet all of the mill management. Of interest, when I started working with the pipemills, our special fused pipemill fluxes sold for about $0.13/lb, while Lincoln bonded fluxes sold for about $0.08/lb. The flux was still being purchased from the Metals Company for a cost of about $0.03/lb! Needless to say, maintaining the flux business for this very large application segment, line pipe manufacture, was an important objective!

Why All AC Power

Norm Schreiner helped me understand the reason for all AC power from his past experience. When DC power was employed at higher currents (> 800 to 1000 amps) arc blow produced erratic weld results. By using all AC power the negative effects of arc blow are significantly reduced. This was reinforced in a number of instances in my many visits to help pipemills improve weld quality. One was in a pipemill near Monterrey Mexico. I had visited the mill years before when it used a two wire AC AC Scott connected SAW system. The mill had recently bought new DC-AC equipment from Lincoln and when I saw the over 25 ground leads on the copper backing bar, I asked if they had grounding problems. The manager said yes, when they installed the new equipment. I then asked if he had lack on penetration at the finish end of the weld. He looked at me as to say, how did you know? I had seen this before since the DC arc would blow backward as the weld approached the pipe end! Over the years I have found ground locations are much less of a problem with AC power!

Sidebar, Why Use DC Power?

There was a significant economic reason for Lincoln promoting DC lead power. It is more difficult to make a flux work on AC demanding more costly ingredients for the arc ignition required twice each cycle. The trail AC arc easily reignites in the molten flux created by the DC lead arc. Many bonded fluxes did not work well on AC power. Fused fluxes, unlike bonded, are fully reacted in manufacture and the ingredients used, typical allowed them to work well on AC power!

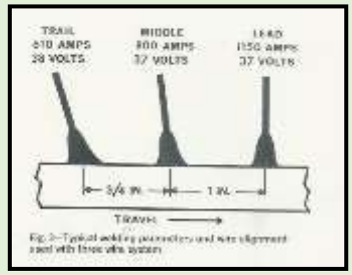
One reason given for using DC power lead is increased penetration over AC. However since welding current with DC is often limited to avoid arc blow, AC amperage can be increased to match the DC penetration. The following is an equation developed by another good friend who taught me a great deal about SAW, Clarence Jackson:

$$\text{Penetration} = K\,(\text{amps}^4 / \text{speed} * \text{volts}^2)^{0.333}$$

(Note; K is dependent on the flux, DC polarity and AC)

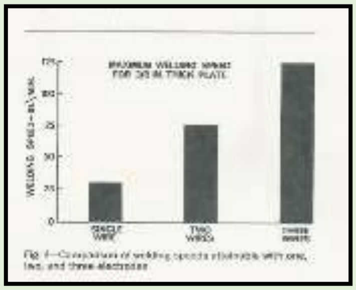
DC electrode positive has ~20% less penetration than DC electrode negative. AC falls in between. Using the above equation, to match the penetration of DC electrode negative at 900 amps requires an increase in amperage of only 5% or 945 amps for an AC arc. With AC there is little worry about arc blow; therefore this can be done without hesitation. However, since the only way to avoid arc blow problems when DC-AC is to reduce the DC current, my experience is that you can achieve more penetration by raising the amperage in an AC-AC system when desired!

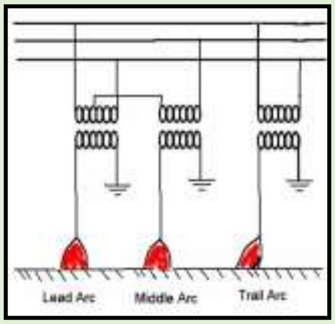
Details of 1968 Three Wire Paper



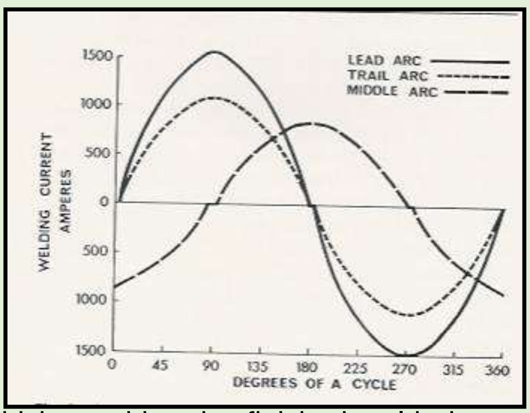
The figure left shows the welding parameters and wire spacing presented in our 1968 paper. After the system was installed in a number of pipemills (the AO Smith/Armco pipemill in Houston had 11 such systems) we found we could weld at 1300 amps lead for thicker sections.

The welding speeds are compared with the best single wire and two wire AC-AC Scott speeds achievable when welding 0.375 wall pipe. Using higher currents for thicker wall pipe provided even higher percentage speed increases.



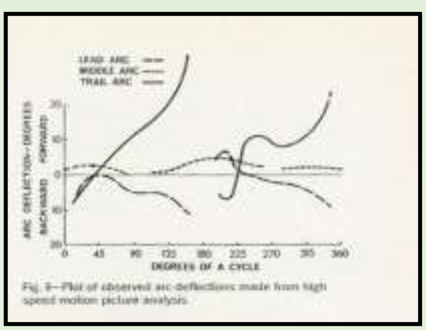


To achive these high speeds with high quality weld shape and weld penetration consistence required the power phasing shown at the left. The lead and middle wires were connected in what is called a Scott connection that places the lead and middle current at 90 electrical degrees from each other. The trail wire,



which provides the finished weld shape, is in phase with the lead. The figure above is a simulated oscilloscope trace of all the welding currents.

High Speed Photography Results



The figure left shows the actual arc deflections measured in the frame by frame analysis of the arcs observed operating without flux. Note the trail arc starts with a slight backward tilt then sweeps forward along the welding axis. Note, this occurs twice each cycle. The middle arc, being pulled on by both the lead and trail wire magnetic fields, does not move appreciably.

A mathematical model was developed that used a phenomena defined by Bachelis in a

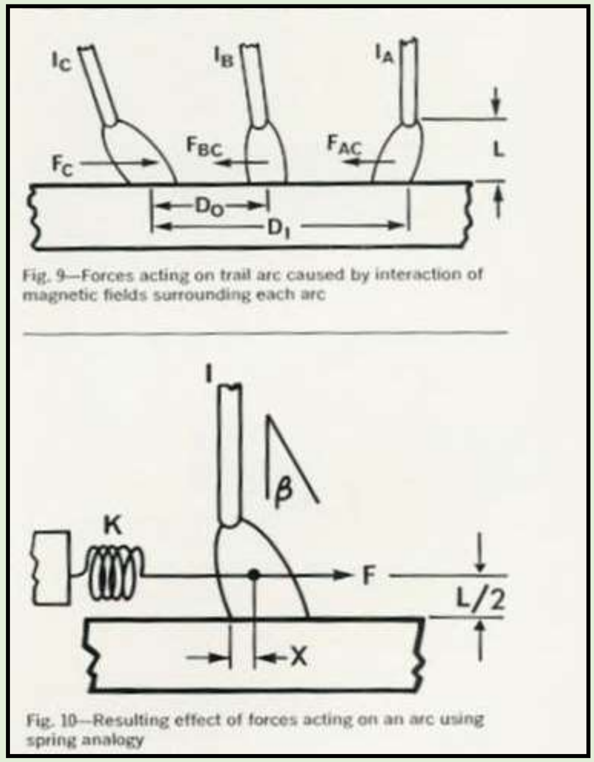


Fig. 9—Forces acting on trail arc caused by interaction of magnetic fields surrounding each arc

Fig. 10—Resulting effect of forces acting on an arc using spring analogy

July 1963 Russian paper published in the English translation of Welding Production. It indicated an arc behaves like a spring and requires a force to have it deflect. Another paper by Muller at all, The Welding Journal August 1951, defined that the arc will tend to follow the angle of the wire because of the self-induced concentric magnetic field. The amount of deviation is dependent on current density. Combining these characteristics yield the following equation:

$$\theta_C = \frac{\alpha}{2} + \arctan C_0 \frac{L^2}{I_C}\left[\frac{I_B}{D_0^2} + \frac{I_A}{D_1^2}\right]$$

The equation can be applied to each of the three arcs to define how the model compares with the actual results observed in the high speed pictures.

The following are the three graphs:

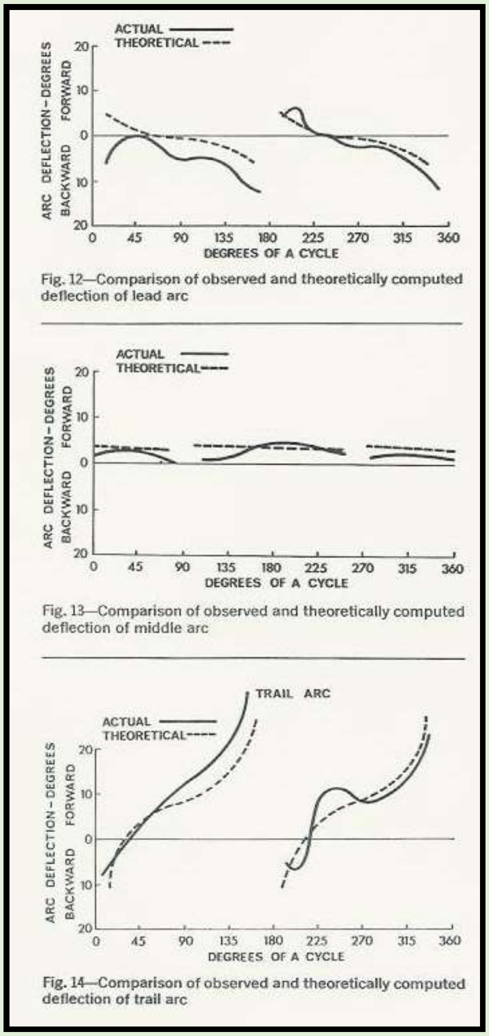


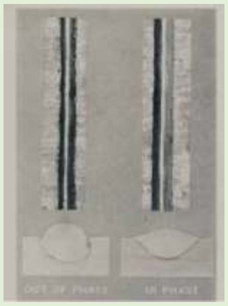
Fig. 12—Comparison of observed and theoretically computed deflection of lead arc

Fig. 13—Comparison of observed and theoretically computed deflection of middle arc

Fig. 14—Comparison of observed and theoretically computed deflection of trail arc

The constant C_o was adjusted to provide the best fit. However the value was kept constant for all of the calculations. You can see the model does an excellent job of matching the observed deflections. The model does not consider the ground current direction in the plate; however that is a more diffuse field and the forces generated have less effect on arc movement.

Reverse Phasing.



Perhaps the most dramatic result is that shown in the first picture in their report, repeated left. When the trail phasing was reversed so it was 180 degrees out of phase with the lead, the weld results was humped and severely undercut. The model shows with this phasing the arc will sweep backward, starting slight forward and sweeping back. This helps push the molten metal backward and prevents it from filling the gouge cut by the lead and middle arc.

Sidebar, Extensive Research Required

I have always been appreciative of the R&D time and cost we were allowed to spend to achieve this result. It was an era when there was sufficient profit to have a young engineer and technician spend several years in the effort. I was obtaining a Masters Degree and was taking several courses in statistical design of experiments. With the many variables involved, amps, volts and spacing of each wire and the various power phasing options only a partial factorial experiment was possible. I recall we used the random selection for each weld test and therefore several welds were required just to set each variable. That was frustrating to the technician, who is my coauthor of the paper, Joe Messana. Joe was justifiably promoted to a development engineer after our lab and field work. As mentioned, we were fortunate that during this time period product flux cost of ~$0.03/lb while the selling price was ~$0.13/lb justified spending the time and cost.

I recall the comments made about the remainder of our very large R&D lab at the time being paid for by the profits from Argon! I'm sure that was true as Argon was selling for more than it is today and it is essentially a byproduct of Oxygen and Nitrogen production! Linde, at the time, had a dominate position in the steel mills which were going gangbusters. They had very large liquefaction plants located at the steel mills around Chicago and Pittsburg. They had the foresight to install very expensive Argon distillation columns in these plants where some competitors would build less expensive plants for only Oxygen and Nitrogen production. I recall some years later, after becoming the Laboratory Manager for the Welding Materials R&D and moving to corporate office to manage a market development effort, we had about 50% of the US production capacity for Argon. We had about a 33% market share and sold the remaining Argon to competitors! I recall the Argon product manager saying my market development group's job was to keep demand higher than supply to support the high prices!

Save Shielding Gas Waste

The high Argon demand – short supply situation exists today and is why Argon prices are escalating 20 to 30%/year!

If you enjoyed reading about this historical SAW research, you'll appreciate the information in the next two sheets that shows the results of the R&D work done in the past 10 years. It resulted in a US patent, # 6,610,957 that describes a simple, very effective product that cuts the MIG (and TIG) shielding gas starting surge waste by 80 to 85% and overall shielding gas use by 50%! Thousands of systems are in use.

The Average MIG Welder Wastes Over 3 Times the Shielding Gas Being Used! The "Gas Blast" at Each Weld Start is a Major Cause; Our Patented Gas Saver System Reduces This Waste

How Much Gas Can Be Saved??

The best way to show the savings is with examples from our industrial customers who tested the Gas Saver System, then purchased systems for all their welders.

Texas Truck Box Manufacturer

This fabricator evaluated the patented Gas Saver System (***GSS***) on a repetitive job, welding doors. With their standard gas delivery hose they welded ***236 doors*** with a full cylinder of shielding gas. Just substituting their gas hose with our patented ***GSS,*** maintaining the same flow settings they welded ***632 doors***! That's a 63% reduction in shielding gas use. They bought systems for all 35 MIG welders.

Weld Performance Improvement

A small shop owner provided this feedback after he purchased a 3 foot ***GSS*** for his small MIG welder. Al Hackethal reported these findings: "

"Well, I can't believe it. I never thought a hose could make that much of a difference. I had a small job that's been waiting for a while. The weld quality, and even penetration is considerable better. Almost no spatter! The weld seemed to be hotter and I turned my MIG down a notch.

Initially thought that my imagination had kicked in, but then realized that the gas I'm buying is actually working the way it's supposed to. Glad I found your website. This is one of the few things that really works better than any info could suggest. I understood the theory, though in practice I understood much better after the first couple of welds. Now I have better looking welds and almost no spatter, which means less grinding and finish work! In addition, the tip was cleaner after the job I just did. This will provide savings in time, labor and maybe even consumables too. As a one man shop there's never enough time for anything.

Thanks for making the product affordable".

EVEN A 6 FOOT *GSS* SAVED 25 to over 40% of SHIELDING GAS

A manufacturer of automotive exhaust systems employs 128 MIG Robot Welders. They have only 6 foot shielding gas hose from the flow control at the gas source to the gas control solenoid. After a large number of tests of the ***GSS*** conducted during a Black Belt Lean Manufacturing Study, the welding engineer measured from 25 to over 40% shielding gas savings depending on the specific weldment tested. They quickly installed ***GSS's on*** all 128 of their Robotic Welders.

In addition, the controlled amount of shielding gas delivered at the weld start, at a starting flow rate that DOES NOT pull air into the gas stream, may improve weld start quality with reduced spatter. It could allow the elimination or reduction of preflow time. With the ***GSS*** optimum starts are achieved without wasting excess preflow cycle time.

Since the ***GSS*** retains the systems higher gas delivery pressure it maintains Automatic Flow Compensation. In Robotic Welding operations, high duty cycles can clog welding gun gas passages such as the gas diffuser and nozzle with spatter. The conduit gas passage often doubles as the hose holding the wire spiral liner and can partially clog with debris from the welding wire, requiring the Automatic Flow Compensation feature built into quality MIG gas controls.

A Professional Street Rod Builder Had This to Say About the *GSS:*

This shop uses a 250 amp MIG welder with built in feeder and a 6 foot gas delivery hose. With their standard gas delivery hose the peak shielding flow at weld start was measured at 150 CFH, far more than needed and enough to pull air into the shielding stream. Air is then sucked into the gas stream causing poor weld starts and possibly weld porosity.

With the ***GSS*** replacing their existing hose, the peak flow surge at the weld start was about 50 CFH and it quickly reduced to the 25 CFH setting. With the many short welds made and frequent inching of the wire, they used less than half the gas and had better starts.

Kyle Bond, President, indicated a big benefit is the reduced time and effort changing cylinders since it's required less frequently. He quickly saw the improvement achieved in weld start quality as a significant advantage! Kyle, an excellent automotive painter, was well aware of the effects of gas surge caused by pressure buildup in the delivery hose when stopped. He has to deal with the visible effects in the air hose lines on the spray gun in his paint booth! It's too bad we can't see the shielding gas waste as Kyle can the effects of excess pressure when he triggers his spray gun! The paint surge is visible and creates defects unless the gun is triggered off the part being painted! Kyle can manage the surge by triggering the paint gun off the part; unfortunately we can't start our weld with the MIG gun off the part ! The ***GSS*** has a built in surge flow limiting orifice that keeps the peak flow from becoming excessive. So you not only save gas you improve your weld starts!

How Does The *GSS* Work?

Gas waste occurs every time you pull the MIG gun trigger even if it's only to inch the wire to cut off the end.

To keep flow at the preset level the gas pressure in the cylinder regulator or pipeline will be between 25 and 80 psi. However to flow shielding gas though the welder and gun typically requires 3 to 7 psi depending on restrictions. Therefore every time welding stops the pressure in the gas hose increases and can store up to 7 times the hose volume of gas. This excess gas "blasts out" at every weld start causing waste and quality issues.

The patented ***GSS*** stores 80 to 85% less gas then typical shielding gas hoses. In addition to reducing wasted gas, the "gas blast" causes air to be pulled into the turbulent shielding gas stream created! It's like starting with the gas cylinder shut off causing excess spatter!

SUMMARY:

The ***GSS*** can cut your gas use in half or more. It also has a surge restriction orifice built into the fitting at the welder- wire feeder end that improves weld start quality.

All that is required is to replace the existing gas hose from cylinder or pipeline gas supply to welder/wire feeder with our patented *GSS*. *It is available in various lengths at* www.NetWelding.com .