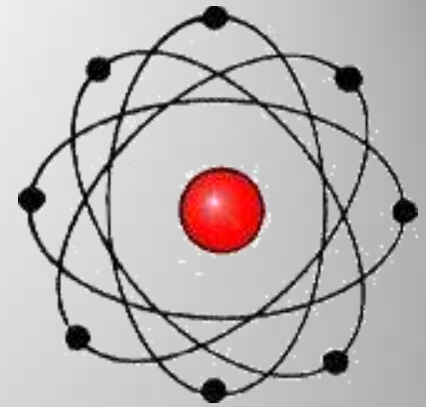




MIG Science

Essential for

Cobot Welding



**Home Study Course for MIG Welders, Welding Students,
Welding Supervisors, Welding Engineers.
Make Better, Consistent, Cobot MIG Welds**

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Introduction

MIG Science is essential for Cobot Welding

Why This Cobot Welding Home Study Course?

This Home Study course was prepared after watching a demonstration of the Cobot MIG Welder acquired by Florence Darlington Technical College.

The FDT Welding Program Director, Willis Ford left, Danny Martin Welding Program Manager, center and myself, Jerry Uttrachi, right. Willis demonstrated



the ease of programming the Cobot and putting it thru its welding paces. Impressive. Willis and Danny discussed visiting several fabricators in the area in their brand selection process. The ESAB Cobot was favored for its ease of programing and maintenance compared to others that

had been tried by fabricators. One had another brand still not operating properly. In that overview it was clear a Cobot fit the fabricators in our area with varied work not high-volume repetitive parts. Some Robot MIG users of our Gas Saver System, like Tenneco with 125 MIG Robots welding OEM Exhaust systems or Harley Davidson 90 MIG Robots making motorcycle frames do have high volume. But the Cobot is more flexible and easier to program for varying parts.

It changed my view developed starting in 1983 when we partnered with Unimation and developed a microprocessor controlled MIG welder that communicated digitally with their new 5 axis electric Robots. Our Regional Sales Engineers found then, and it has mostly persisted, most fabricators parts do not have the tight, consistent fit-up to effectively utilize a MIG Robt.

I also thought a Cobot operator or folks managing Cobot MIG welders need additional “MIG Science”. It’s important for manual MIG welders but essential for Cobot welding where a human is not watching the leading edge of the weld puddle and making minor adjustments for weld seam variations, etc. BUT our Free 90-page Home Study Course, “***Welding Math and Science***” is more than most need or may want. https://netwelding.com/Welding_Math_Science_WMS.pdf So prepared this shorter Home Study Course focused on MIG Cobot Welding. It covers the Science of what makes MIG wires melt, that if understood and properly controlled effects weld penetration. Hint ***It’s NOT the HOT ARC!***

The Following is My Background in Automatic and Robot Welding

I started my welding career in US Linde's Welding R&D Lab in 1964 as a Development Engineer working on Submerged Arc Welding (SAW.) It was one largest welding R&D Labs in the country with ~125 professionals.

In the mid 1930's the company had purchased the early patents on a welding process they called Unionmelt. It used patented fluxes and mostly remained secretive for War security. After the War it was referred to as Submerged Arc Welding (SAW) as a generic name. I was fortunate that an Assistant Lab Manager, Clarence Jackson had worked on the early process development. They made X-Ray motion pictures of the "Arc" under the flux! He wrote many technical papers on the subject and was "my eyes" under the flux (*along with an oscilloscope on my Lab weld station.*) His AWS Adams Lecture "The Science of Arc Welding," was published in the AWS Welding Journal. See Reference 1 in the Appendix.

Submerged Arc Welding Was Very Productive BUT Often Fit-Up Limited in Use



I developed a three-wire SAW process that welded at ~3000 amps and doubled the welding speed making large (>16-inch) OD high pressure gas and oil pipe, produced from flat plate. It made high quality welds, at ~125 ipm and ~65 lbs/hr deposition rate. BUT to utilize its high-speed capability it required very good fit-up. Most of the 9 US pipemills machined the butting long seam edges in 3/8 to 3/4-inch-thick plate. A weld pass was made inside, one overlapping outside. Welds were 100% inspected with Fluoroscope, End X-Ray and UT. There were >125 of these welding systems installed. Pic is one

of eight installed in the first US Steel pipemill. We evaluated the process for other applications but few could achieve the fit-up and process control necessary.

My Early Experience With MIG Robots

In 1982 was at corporate office in Danbury CT managing a Welding Market Deployment Group. I was approached by Unimation (*one of the World's first Robotic Companies*) also in Danbury CT to develop an integrated MIG system to work with their new, Puma 5 axis electric robots. Our very smart EE Engineer (*and friend*) Ted Toth adapted his innovative Microprocessor based DigiMIG. The Robot communicated with the DigiMIG digitally and controlled Start, Stop, WFS, Voltage, Pre and Post Gas Flow.

We did not sell or service the Robot, that was left to Unimation. The business plan I developed was not based not on selling MIG Welding Robot equipment as it was a relatively small dollar one-time sale. Nor based on selling MIG wire as the solid MIG wire used was a commodity with only moderate margin. BUT the sale of Argon (*where we controlled 60+% of the US production and market price*) flowing thru a Welding Robot was very profitable. The objective was to demonstrate making parts for a Fabricator and gaining a multiyear Argon supply contact! We were given a Robot for each of our 6 Reginal Demo Centers.

The Problem

Our Reginal sales engineers found most companies could not get the consistent fit-up needed to make quality welds with a Robot. Recall a visit with one of our 6 Region Engineering Managers to the General Manager of a fabricator making Military Tank Turrets. He wanted to replace their manual MIG welding with MIG welding Robots. The multipass welds were made in odd angle (*to help deflect projectiles*) single bevel “V” joints in ~3/4-inch-thick high strength Armor plate. The joint gaps varied from a tight butt to a 1/4-inch gap. Although Unimation had developed a rudimentary “*Thru The Arc Seam Tracking System*,” dealing with the varying gaps was not viable. Recall the fabricator Manager said, “*But our manual welders do it all the time!*” Yep, BUT the Robot (or Cobot) is not a person!

Enter the Easy to Program Cobot

Unlike Manual MIG, Quality Cobot Welds Require Close Control of TTW

A skilled Manual MIG welder when they approach a non-planned gap in the joint can increase the TTW. Depending on wire size that could decrease current enough to reduce penetration by >20% avoiding burnthrough. A prograded Cobot can’t do that! But the Cobot can use a slight weave technique to apply welding heat to the joint edges, avoiding burnthrough. A Cobot technician observing a wider than planned joint gap can simply apply a weave.

Even in an area where there is not high production of the same part the Cobot fits many fabricators. It’s easy to program and has the flexibility of quickly implementing a weave program where gap management is necessary. BUT where controlling wire contact tip to work is “important” in any MIG welding, without a manual MIG operator observing and reacting to a gap, it’s “critical” for a Cobot to compensate with perhaps a weave.

Another parameter a manual MIG operator inherently handles when looking at the arc is wire placement. As the contact tip wears the wire will move off the desired weld path. A manual welder, watching the arc will just move to correct. A Cobot can’t so replacing contact tips more often is important!



WARNING!



- **PLEASE READ** all material in the notes below this slide.
- **Shielding gases can leak and IN A CONFINED AREAS COULD CAUSE ASPHYXIATION AND DEATH.**
- **Contact with live electrical parts and ground CAN CAUSE SEVERE INJURY AND DEATH.**

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READ AND UNDERSTAND ALL MATERIAL NOTES BELOW EACH SLIDE:

Special precautions must be considered when measuring gas flow, installing gas delivery hose, parts, fittings and devices that use them. Some precautions relate to the properties of weld shielding gases. Although these gases are not generally considered harmful under normal circumstances they are usually heavier than air. Thus they will sink to the floor level **AND IN A CONFINED AREA COULD CAUSE ASPHYXIATION AND DEATH.** All connections should be checked for leaks with an approved leak detection solution. Shut off shielding gas supply when not in use.

Some procedures such as checking flows at the MIG torch nozzle may involve having the welding power energized. Be very careful since the contact tip and the welding wire will be electrically energized if you use the torch trigger to activate the gas solenoid. Keep hands away from tip and wire or you could be shocked. The welding wire must be prevented from feeding, however do not fully remove it from the torch and feeder since that may increase backflow of gas. Just disconnect the pressure rolls and test to be sure the wire does not feed. A test is suggested for defining why MIG welding wire melts which could be dangerous if not properly conducted. Be sure to follow all the precautions suggested.

CONTACT WITH LIVE ELECTRICAL PARTS AND GROUND CAN CAUSE SEVERE INJURY AND DEATH.

These statements are **NOT MEANT TO BE COMPREHENSIVE** in regard to the use of the welding products employed. Please carefully read and follow the manufactures instructions. Also refer to publications on safe practices for welding and cutting available from the American Welding Society, 8669 Doral Boulevard Suite 130 Doral, FL 33166 including "Safety in Welding and Cutting" – ANSI/AWS Z49.1.

Module 1

Why MIG Wires Melt

MIG Science

Essential for

Cobot MIG Welding

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Module 1

Understanding what causes a MIG wire to melt provides excellent insight on what causes changes in important parameters such as weld current, deposition rate and weld penetration.

Definitions

- 1) *Hate sounding like a Doctor when talking with welders or shop folks using American Welding Society unpronounceable acronyms GMAW and GTAW so use MIG and TIG.*
- 2) *I use current and amperage interchangeable (which is technically correct.)*
- 3) *I often use TTW (tip to work) formerly Contact Tip to Work Distance (CTWD.) I and others also refer to it as "stickout." Some also attempt to define it as the amount the wire sticking out of the contact tip to the ARC. That is hard to measure and my reference to TTW is simple: The length of wire when not welding from the end of the Contact Tip to the Work.*
- 4) *WFS (wire feed speed) is a critical parameter in MIG welding as it is what determines the key variable "Current," the key parameter controlling weld penetration.*
- 5) *I typically use Manual MIG welding for what is also called Semi-Automatic MIG Welding (the welder holding and moving the MIG Gun.)*
- 6) *Note: if a student and the Instructor says use GMAW and GTAW, follow, they are correct and give out grads! Smart to do as they say! LOL*

What's Coved in Module 1

- What Causes a MIG wire to Melt?
- Hint:
 - It is **NOT** the Hot Arc
 - The wire or molten drops passing trough the Arc
 - Radiation from the Arc
- Two key factors cause the wire to melt and have a major effect on other parameters like:
 - Weld penetration
 - Weld metal deposition rate

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Module 1

Very Important to Understand What Causes MIG Welding Wire to Melt? Hint: this is what it is NOT:

a) the “hot arc”, b) radiation from the arc or c) the wire passing through the arc.

Two phenomena are primarily responsible for wire melting:

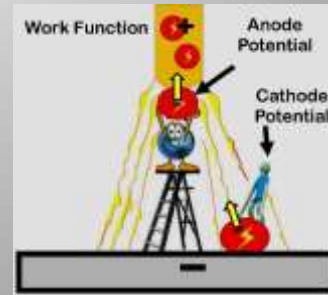
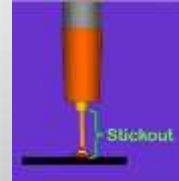
The first reason is wire Stickout (TTW, the distance between the tip and the work piece.) As the wire passes from the end of the MIG gun contact tip to the arc, it is carrying all the welding current thru a very small cross section wire. It's at room temperature as it exits the Contact Tip and can exceed 500 degrees F before the arc forms at the end (depending on the “Sickout.”)

The second reason the wire melts is that current leaving or entering a surface, be it wire tip or hot puddle, requires a large amount of energy for the electrons to enter or leave that surface. This energy, generated at the surface, melts the already hot wire. Assuming Electrode Positive this is referred to as Anode Potential, also called Work Function expressed as Volts (the units are electron Volts or eVolts.) The energy required is equal to Amps * Anode Voltage.

Two Items Are The Major Cause

- What causes a MIG wire to melt?
- The two major factors are shown graphically
 - The top sketch is the first, the wire heats due to current passing through it on the way to the workpiece (actually the Arc.)
 - The bottom sketch shows that to get electrons into and out of a solid takes a great deal of energy. This is called the work function (units, *volts*)
- These two factors are the major cause of wire melting

Video Link Provided Below:



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Module 1

The following equation obtained from Reference (1) in Appendix, defines the relationship:

$$\text{Wire Melting Rate (lbs/hr)} = a * \text{Amps} + b * \text{Wire Stickout} * \text{Amps}^2$$

Where "a" and "b" are constants and "Wire Stickout" is the distance from the torch contact tip to the work piece measured in inches. The approximate values for "a" and "b" for 0.035 inch diameter carbon steel wire are: a = 0.017; b = 0.00014. (Note: I use the spreadsheet * symbol for multiplication versus X.)

These two energy sources cause the wire to melt. The first term (a * Amps) is the Anode Voltage (or *Work Function also stated as eVolts*) times current. The second term defines the energy input due to resistance heating of the wire as it passes from the end of the MIG contact tip to the workpiece (actually arc while welding BUT I always measure as TTW. Note these are engineering approximations.

For a more detailed explanation you can watch this Video, one of 4 Similar Video Links presented in the Appendix under References:

Welding Math Deposition and Penetration:

<http://www.youtube.com/watch?v=O8zz-Nb0q9Y>

Stickout Change Causes Current Change

If the welding wire feed rate remains fixed and “Stickout” increases, the welding current decreases

Melt Rate lbs/hr	Stickout inches	Amps
5.5	3/8	200
5.5	1/2	184
5.5	5/8	172
5.5	3/4	162
5.5	7/8	154

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Module 1

One major implication of increasing MIG wire “Stickout” at a fixed wire feed speed, as “Stickout” increases the very efficient resistance heating increases and less current is needed. BTW, the very efficient process, called “Hot Wire” (used in TIG, MIG, SAW, Laser and other processes, is very efficient. It only uses resistance heating to bring a cold wire exiting a contact tip to almost melted temperature with only 10 to 15% of the energy typically used to melt MIG wire!

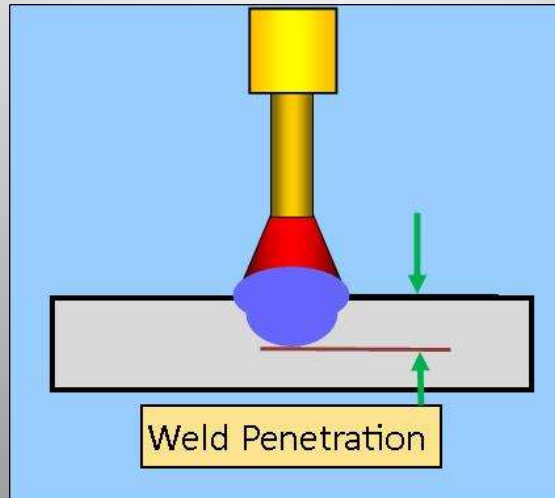
The second term includes wire Stickout and the current squared. It is very influential in controlling wire burn-off or deposition rate.

$$\text{Wire Melting Rate (lbs/hr)} = a * \text{Amps} + b * \text{Wire Stickout} * \text{Amps}^2$$

As seen in the above table for a fixed wire feed speed resulting in a deposition rate of 5.5 lbs/hr the welding current at a short sickout of 3/8 inches is 200 amps. If the Stickout is increased to 7/8 inches the current decreases to 154 amps. The same amount of metal is deposited since the wire feed speed did not change. However, the amount of amperage is, in this case, is 23% less $([200-154]/200)$ The weld metal is deposited with less energy and could cause a cold, unfused area in the weld deposit if the TTW is too long.

If you would like to learn more about the math and apply the equation in EXCEL Download our other Free Home Study Course:
https://netwelding.com/Welding_Math_Science_WMS.pdf

The Second Implication of Lower Current is Lower Penetration



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Module 1

The Math Equation that Defines Weld Penetration is Most Dependent on Welding Current:

A major implication of the wire melting relationship is with increased Stickout (at a fixed wire feed speed) amperage will decrease. That has a significant effect on another parameter, weld penetration.

Weld penetration can be determined by an equation defined some years ago by C. E. Jackson in Appendix Reference (1) Again an engineering approximation.

Weld Penetration (distance into the base material when making a weld on plate measured in inches) =

$$K [\text{Amps}^4 / (\text{Weld Travel Speed; ipm} \times \text{Volts}^2)]^{0.333}$$

For 0.035 inch diameter solid carbon steel wire, the approximate constant K = 0.0019

If you would like to learn more about the math and apply the equation in EXCEL Download our other Free Home Study Course: https://netwelding.com/Welding_Math_Science_WMS.pdf

Or if you rather watch video's than read:

1. Welding Math Deposition and Penetration:
<http://www.youtube.com/watch?v=O8zz-Nb0q9Y>
2. Welding Math Deposition and Penetration Spreadsheet:
<http://www.youtube.com/watch?v=cuAbV3FHwQw>

The Second Implication of Lower Current is Lower Penetration

Stickout inches	Amps	Penetration inches	% Loss
3/8	200	.127	base
1/2	184	.114	11%
5/8	172	.104	18%
3/4	162	.096	24%
7/8	154	.090	29%

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Module 1

Repeating because of importance: The math equation that defines weld penetration is very dependent on welding current:

A major implication of the wire melting relationship is with increased Stickout (at a fixed wire feed speed) amperage will decrease. That has a significant effect on another parameter, weld penetration.

Using the penetration equation we find the following when we change wire Stickout for 0.035 inch solid wire. Assuming a fixed wire feed speed that produces 200 amps at 3/8 inch wire Stickout:

Weld Penetration (distance into the base material when making a weld on plate measured in inches) = $K [Amps^4 / (Weld Travel Speed; ipm * Volts^2)]^{0.333}$

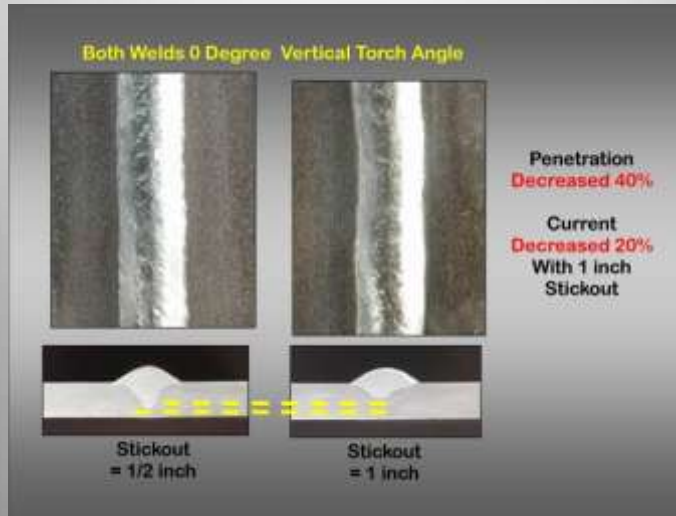
(When putting values in the equation, always calculate the values within the parentheses first, i.e. multiply travel times volts first.

For 0.035 inch diameter solid carbon steel wire, the constant K = 0.0019

Using the previous reduced current data for Stickout changing from 3/8 inches to 7/8 inches shoes the weld penetration reduced from a base of 0.127 at 3/8 inch Stickout to 0.090 when the current reduced to 154 amps at 7/8 inch Stickout.

That is a reduction of 29% $[(0.127-0.090)/0.127]$

Example of Increased Stickout Leading to 20% Lower Current and 40% Reduced Penetration



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Module 1

This is an actual weld example of increased Stickout with the same WFS going from 1/2 inch to 1 inch. That caused a 20% reduction in current and a 40% reduction in penetration.

If the weld being made requires full penetration than this increase could cause a lack of fusion defect. The importance of holding a fixed MIG gun contact tip to work distance is emphasized by this example.

At times, particularly on thin material this characteristic can be used to advantage in manual MIG welding BUT not Cobot welding. If a joint gap increases and the weld has a chance of burning through, increasing the Stickout will reduce current and may prevent the burnthrough. The equation should be used as a guide, it may not give exact values since we are not including material thickness etc. However, I have found the relationships are accurate and provide the penetration differences welding on a given material thickness. May have to develop your own constant valves by making several welds.

Module 2

MIG Wire Placement is Important

MIG Science *Essential for* Cobot MIG Welding

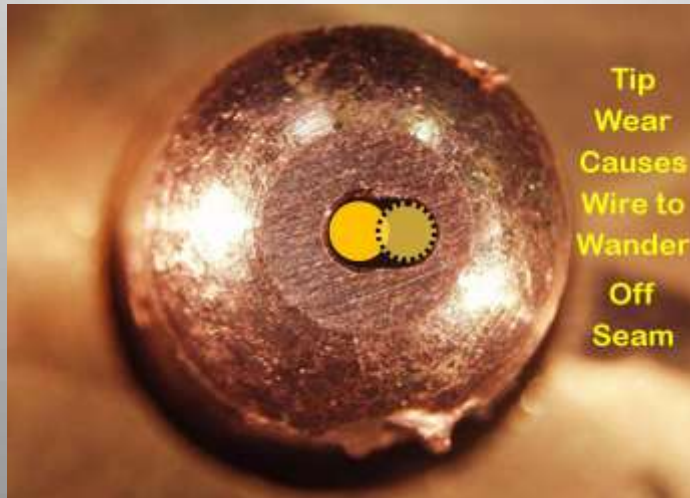
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Module 2

Consistent MIG wire placement in the joint is very important

Contact Tip Wear Causes Wire Wander



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Module 2

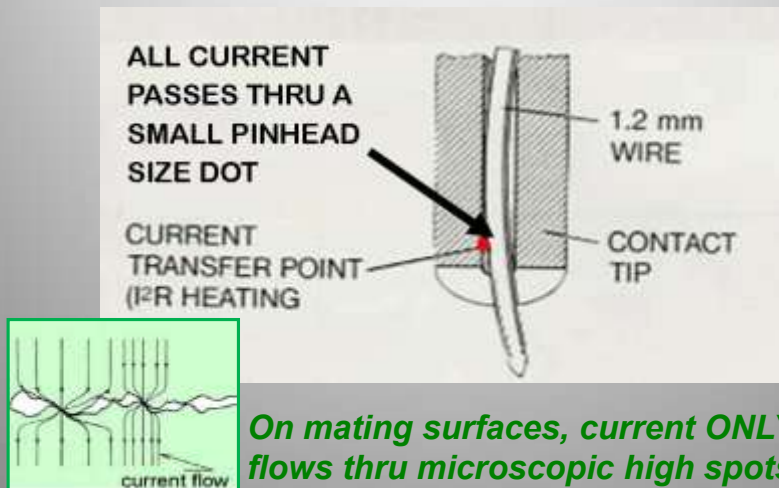
CONTACT TIP WEAR:

Where a manual MIG welder, watching the arc can compensate as contact tip wear causing wire to wander from the desired path; a Cobot Cannot. Must replace contact tips more often in Cobot MIG welding and other automatic MIG welding.

CURRENT TRANSFERS TO THE MIG WIRE THRU A SMALL PINHEAD DOT SIZE AREA AT THE END OF THE CONTACT TIP!

IT'S NOT CRITICAL to understand why TIP wear occurs as it is observed by just looking. However, it may be of interest. I was made aware that all current flows thru a small pinhead size DOT area at the end of the contact tip soon after I started working in Welding R&D in 1964 by Gus Manz a Lab colleague and friend. Gus is a brilliant EE who had most of our many Linde Patents re Welding Power Sources and other processes like "Hot Wire TIG" etc. Welding current flowing thru a small size DOT has a number of implications in welding, which I discovered can help when troubleshooting weld problems. I find it very interesting and useful today. It is a factor determining tip wear.

All Welding Current Transfers Thru one Small Pinhead Size DOT!



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Module 2

CONTACT TIP WEAR:

When a manual MIG welder, watching the arc, can compensate if contact tip wear causes the welding wire to wander from the desired joint path - a Cobot **CANNOT**. Must replace contact tips more often.

Note there are several factors causing tip wear. Mechanical friction of the steel wire in the copper-based tip is one. Especially non copper coated metal and flux cored wires. The copper coating provides some help on solid steel MIG wire. However, there is electrical erosion as the current transfer in a small contact DOT at the end of the copper tip! The high electrical resistance and the small cross-sectional area of the steel wire versus the much larger diameter high conductivity copper-based tip will cause current to flow to the tip end. The combined area/conductivity differences is perhaps 200 times more resistance in the wire. In addition, current does **NOT** go thru all of the mating surface in contact. It goes thru only the high points.

In some cases, such as Pulsed and Short Arc MIG or SAW with large wires where wide current executions occur as large molten drops detach a phenomena called "Skin Effect" may occur.

Quoting: DC current transients create a rapidly changing magnetic field. This changing field induces eddy currents within the conductor that oppose the change, forcing the main current to flow more along the conductor's surface, which is defined as skin effect.

Resistance and Size Wire vs Tip Main Reason

SIMPLE RESISTANCE IS MAIN REASON *

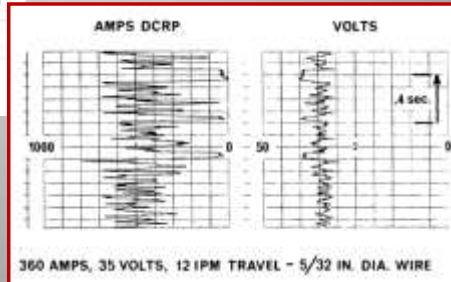
0.045 inch diameter STEEL wire = 0.0025 Ohms/Inch
Copper Contact Tip Resistance = 0.000014 Ohms/Inch
COPPER TIP with larger cross section area and lower resistance is about 200 times less than resistance than wire



* Electromagnetic reasons are another reason for current to flow thru one pinhead size dot

With only 360 amps on a 5/32 SAW Wire, current excursions are very large also affecting the ground current path.
Pic from my 1st AWS Journal Paper

Using a 5/32 wire in SAW with a simple CV power source, caused wide current swings as the large ~5 molten drops per second transferred! The gap after the drop was more than the CV voltage and the arc extinguished and reignited.



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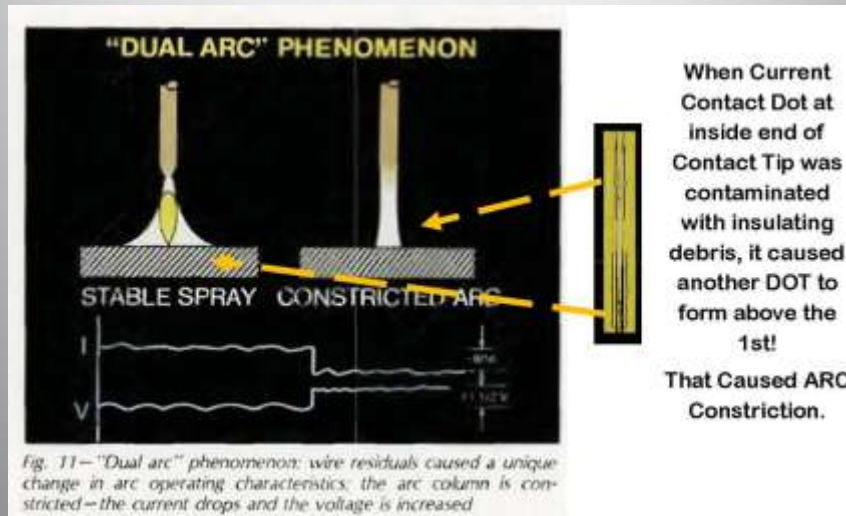
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Module 2

I observed a validation of current flowing thru a small area in our Material Technology Lab in Ohio. I was watching a SAW Demo of a multipass weld on 1-inch-thick plate. The weldment was placed on a large cast iron welding table. It was held down to the table with 4 very large clamps. The ground (work) cable was permanently bolted to the table. With a large weldment contacting the table and clamps tight in 4 places there was a large area where the ~600-amp current could flow. However, I observed a small, hot yellow glow in one corner where a plate corner was touching the table. All current was passing thru that one contact spot as it was the least resistance (if it had been AC power least reactance) path!

Several things could have caused current flow in that one location. First it was probably the lowest initial resistance high point in contact. Then as that small area heated to a visible glow, the steel softened and the clamping forces increased the good contact area. There are also possible electromagnetic and current path effects. DC SAW can have large transient current spikes when a large molten drop forms and releases, as drop frequency can be very low (~5 drops/second) with large diameter wires. As mentioned previously, *DC current transients create a rapidly changing magnetic field. This changing field induces eddy currents within the conductor that oppose the change, forcing the main current to flow more along the conductor's surface, which is defined as skin effect. With current swings there is also an inductive reactance affecting ground current path.*

Two Contact DOTs In Great Tech Paper



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Module 2

CURRENT TRANSFER THRU SMALL PINHEAD SIZE DOT AREA OR WHEN ONE DOT IS CONTAMINATED WITH INSULATING DEBRIS IT FORMS ANOTHER!

A very smart Lab Division Head (*and friend*) in our Material Technology Lab (*which I managed in the mid 1970s*) wrote an excellent Technical Paper on MIG wire feeding and wire quality. The Paper titled *"Reliable GMAW Means Understanding Wire Quality Equipment And Process Variables;"* by K. A. Lytle was published in the American Welding Society Welding Journal in March 1982. Among the many things discussed, he documented that two current passage DOTs occurred in some situations making a dramatic visible change in the arc! The paper discusses how a build up of copper and steel wire fragments can occur where the contact DOT exists. If oxides and insulating debris form on the first developed current DOT a second DOT forms up the contact tip. That produced a dramatic change the arc shape.

Cobot Cannot See Spatter Build-Up



ESAB
JetStream
Robot
Torch
Cleaner



BEFORE AFTER

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Module 2

SPATTER:

You must observe and remove spatter.

Can use a spatter DIP or Spray to help.

There are abrasive blast and mechanical reaming cleaning stations that can be incorporated in the Cobot program to clean nozzle and tip. The ESAB JetStream is a non-contact abrasive cleaner that can also apply Anti-Spatter compound. It's NOT CHEAP but neither is inferior weld quality due to spatter clogging the nozzle causing poor gas shielding! Or damaged nozzle/contact tip from lower cost mechanical reamer type spatter removers!

Module 3

Reduce Starting Gas Blast Improves Weld Starts

MIG Science *Essential for* Cobot MIG Welding



*Our GSS Includes a Patented “Peak Flow”
Limiting Orifice in Wire feeder Hose Fitting,
Improving Weld Starts*

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Module 3

The initial shielding “Gas Blast” at weld starts causes inferior weld start quality. The high surge flow is very turbulent pulling air into the shielding gas stream.

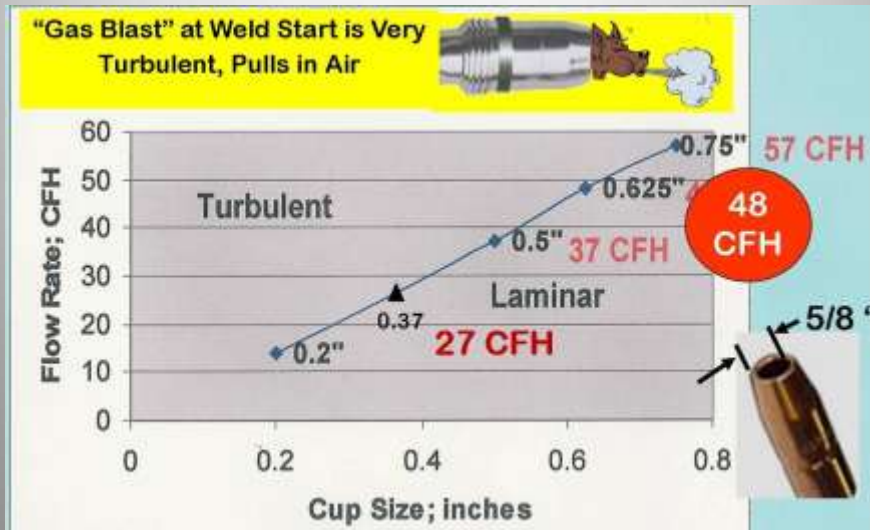
That Chaotic Turbulent gas flow continues for a short time even after the flow velocity is reduced to the desired steady state flow rate.

We’ll Discuss our inexpensive (Starting under \$90) Patented Gas Saver System that not only cuts gas use by about 50% by eliminating waste BUT also incorporates a “Peak Gas Flow” fitting in the wire feeder gas delivery hose end that improves weld start quality, reducing spatter, hash starts etc. It DOES NOT set the steady state gas flow. That is done with any existing “Quality” gas flow control (as are most in use.)

Full details are available in this Link:

<http://netwelding.com/Overview%20GSS%206-08.pdf>

Reducing Starting Gas Blast



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Module 3

Inferior Starts are Caused by the shielding "Gas Blast" at each Weld Start. We have measured over 200 CFH peak gas flow. That is a very Turbulent gas stream that pulls in Air causing excess spatter and possibly internal weld porosity.

Osborn Reynolds in the late 1800s defined that smooth Laminar flow becomes chaotic Turbulent flow at a given flow rate. For MIG welding with a 5/8-inch nozzle that transition flow rate is about 50 to 55 CFH with the commonly use 5/8-inch diameter gun nozzle.. Note UK TWI tests used several measurement methods. One measured oxygen in the shielding gas stream. Overall, they concluded ~48 CFH was the transition from Laminar to Chaotic Turbulent flow.

Reynolds also showed that it takes some time for Chaotic Turbulent Flow to become smooth Laminar Flow even after the flow rate reduces to the Laminar flow rate level.

In addition, Stauffer defined in a 1982 patent that some extra gas is needed at the weld start to purge air from the weld start area. However, that peak flow should not cause excessive Turbulent flow.

In the 1950's BEFORE MIG Short Arc was Developed, most MIG used Spray Arc with small 0.023 and 0.030 diameter wires using ~100 amps. Small ID gas nozzles used max peak flow for Laminar Flow was 30 and 40 Max CFH. US Linde Sold and their successors who bought their welding business still sell a ~40 to 45 peak flow orifice that mounts at the wire feeder to reduce starting Turbulence. It's TOO LOW A FLOW for today's larger nozzles and current.



ESAB Adapt Inline Flow Restrictors | 19X76
 MSRP = \$92.26
 Too Low Peak Flow For Today's MIG Current and Nozzle Sizes

Our Gas Saver System (**GSS**) employs a larger proper size peak flow limiting orifice that has flows that fit today's higher currents and nozzle sizes. It's included on the wire feeder end of the **GSS** hose. Six Foot **GSS** System Sells for \$90!

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Module 3

When I started in welding R&D in 1964, our company, US Linde, knew Inferior Starts were Caused by the “Gas Blast” at each Weld Start.

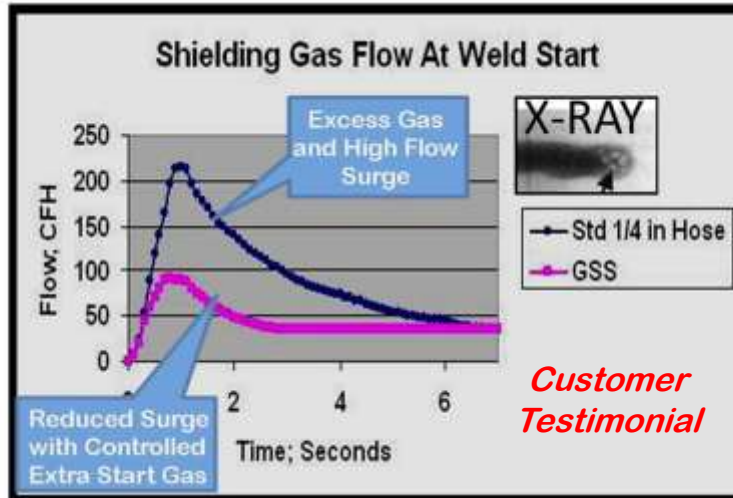
In the 1950's, before short circuiting MIG was developed and widely used, most MIG was done with Spray Arc at in the 100 amps range.

Maximum desired gas flow rate to maintain Laminar flow was ~30 to 40 CFH for the typical 20 CFH flow settings with 0.023 and 0.030 diameter wire using 3/8 and 1/2 inch ID nozzles. Linde sold a simple orifice that mounted at the wire feed gas inlet designed to lower peak flow to 40/45 CFH. That same 1950's part number is still sold today by the current successor of Linde's welding business, ESAB.

We found that max 40/45 CFH flow is too low for today's larger wires, higher currents and nozzle sizes. We incorporate a larger peak flow limiting orifice in our GSS at the wire feeder hose end.

Note a 6 foot GSS with included proper size peak flow orifice in the gas fitting on the wire feeder end sells for \$90.00, less expensive than ESAB's simple 19X76 part number which saves NO GAS. The GSS improves weld starts AND cuts gas use typically by ~50% by eliminating waste from excessive “Gas Blast” volume (by >80%) as well as peak flow rate at each weld start!

A fabricator tested our **GSS** and solved a weld start porosity problem caused by excessive weld start gas flow surge. Weld start porosity was eliminated with the **GSS**. Flow curves show the reason this early user, who documented a 41% shielding gas saving. The welder was very thankful for the improved weld starts. They make high pressure pipe and he was frequently having porosity detected at weld starts by the required Ultrasonic Testing. That required rework. He told me he knew the cause was the high initial gas surge. You can see from the graph the high, peak flow was 225 CFH and excess lasted for about 5 seconds. Welding with the **GSS** for ~6 months, the welder said that his prior frequent UT rejections were eliminated.



Customer Testimonial

We tested a GSS at a shop where we had worked with the welding engineer improving weld quality. In his repair and cross seam weld station we evaluated the potential GSS gas savings (*which after measurements over time turned out to be 41%.*)

When we started the first test weld the welder expressed great performance! NOT in gas saving, which could not be seen, BUT in the reduced “Gas Blast” at the weld start he observed. He was sure the internal porosity found often found at his repair weld starts that required UT inspection was caused by the high starting gas blast. Can see from the gas rate flow plots we made what he was up against. The peak gas flow with his standard gas delivery system to the wire feeder was ~225 CFH. That was way above the Turbulent flow rate of 50/60 CFH for his 5/8-inch nozzle size. It lasted for over 4 seconds. That was pulling in air causing the observed subsurface porosity on UT inspection!

MIG Robot User Improves Weld Starts With **GSS**

A manual MIG welder learns to make a small scratch move when starting that helps get the arc started (similar to starting with stick.) A Cobot can't do the same. BUT controlling the peak starting gas flow can be a big help with weld starts.

Customer Testimonial



Anel Corp is a custom fuel tank fabricator. They reported these results after their test of a **GSS** on a MIG robot. *"Immediately the arc starting problems went away. There have been little to none of the intermittent arc starts caused by the initial gas surge since converting over to the **GSS**. With our standard setup, approximately 1 out of every 3 arc starts had the "popping" arc starts associated with the gas surge and purge issues."*

They purchased 50 **GSS**s. Well over 15,000 are being used in industry.

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Module 3

Customer Testimonial:

Improved MIG Robot Weld Starts with GSS.

The high "Gas Blast" at weld starts pulls in air making inferior weld starts with excess spatter. Almost like starting in air. By controlling the peak flow rate, starts improve as observed by this Welding Engineer who emailed his GSS test results.

After the test, the company put GSS systems on all their 50 MIG Robots.

User Improves Weld Starts With **GSS**

Customer Testimonial



**Although NOT a
Cobot MIG
Welder . It could
have been used**

Brad Fenley, an Argyle TX fabricator, called requesting a 6 foot long (FB6) **GSS** shipped overnight. He had a job to complete for a customer and was getting weld start porosity on most parts. He had adjusted all welding parameters including gas flow rate without improvement. He could hear the shielding gas surge at the weld start and found our web site that discusses how porosity can be caused by the turbulent "Blast of Gas" pulling in air. He uses a good MIG Spray Arc gas mix, 98% Argon/2% Oxygen, welding a carbon steel tube to a base. We sent the Gas Saver System by Express Mail, and it arrived the next day. Brad sent this email, "After putting the **GSS** hose on I have some of the **best looking welds I've seen. I think out of 50 parts, I only had 2 or 3 to clean up. Thanks for the help.**"

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Module 3

Customer Testimonial:

Improved MIG Weld Starts with GSS.

Although an automatic fixtured MIG welder, not a Cobot or Robot, the start improvement from reducing the initial "Gas Blast" was dramatic. We have many GSS customers where improved start quality is as or more important than the typical 50% gas use reduction!

Appendix

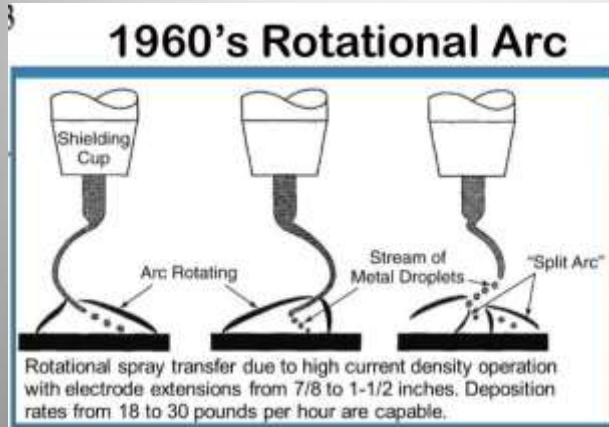
MIG Science *Essential for* **Cobot MIG Welding**

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Some additional information provides possible MIG process variations to increase welding speeds etc. These high deposition variants are not new but difficult to implement by Manual MIG Welders.

The Appendix also includes additional references.

Cobot Can Handle Hi Deposition MIG



A Problem With 1960's Rotational Spray, defined by Airco: it was NOT stable below about 18 lbs/hr.

Sounds like a so what, but not so easy handling all that metal and heat!

We had a 1987 patent of a MIG Process that welds from 10 to 25 lbs/hr

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Rotational Arc was reported by Airco in 1958. Reference: That was reported in a technical paper titles: GMAW, A Reliable Process on the Move" by K.A. Lyttle American Welding Journal March 1983, Vol 62.

As the MIG wire heats from I^2R resistance it becomes very soft, thin and flexible. Electromagnetic forces cause it to spin rapidly BEFORE molten drops form and transfer to the work.

There is an unstable region from maximum stable Spray Arc to Rotational metal transfer. Therefore the process can ONLY be used at high WFS and deposition. Dealing with all the large amount of weld metal at relatively low current for the WFS (*since longer than normal TTW extensions are used*) can cause weld metal to roll ahead of the arc.

I recall a manual MIG welder had be sure they were staying ahead of the molten puddle, similar to when Short Arc welding. The process was also very hot and water cooled high current capable MIG Torches were required.

Cobot Can Handle Hi Deposition MIG

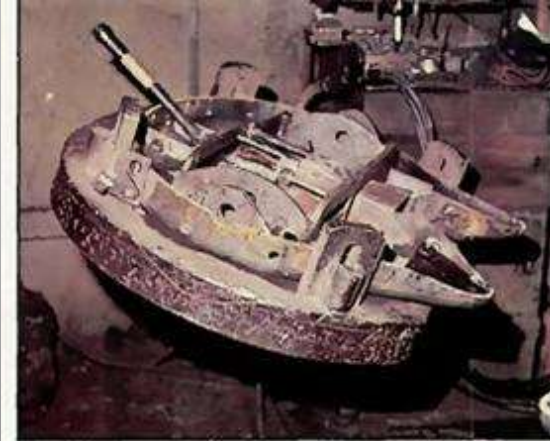


Fig. 12— "Fifth wheels" are joined to truck tractors using rotating spray transfer due to the extremely high productivity levels that can be achieved with this process

The Problem With Rotational Spray, it is NOT stable below about 18 lbs/hr.

Sounds like a "so what," but not so easy handling all that metal!

Left is Pic of one application shown by Kevin Lyttle in AWS Paper March 1983 (see reference in Notes below.)

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In a published technical paper in the AWS Welding Journal Keven Lyttle discusses a MIG process using very high WFS of 0.035-inch diameter wire. The application required a very large fillet weld on 5th wheels.

***GMAW, A Reliable Process on the Move" by K.A. Lyttle
American Welding Journal March 1983, Vol 62.***

United States Patent [19]
De Vito et al.

[11] Patent Number: 4,645,903
[45] Date of Patent: Feb. 24, 1987

[54] GAS METAL ARC WELDING PROCESS

[75] Inventors: Joseph De Vito, Ashabala; Kevin A. Lytle, Mentor; Ronald D. Sutton, Ashabala; Alan J. Westendorf, Shaker Heights, all of Ohio; Nils E. Larson; Gerald D. Utmacht, both of Ridgfield, Conn.

OTHER PUBLICATIONS

Cary, Howard B., *Modern Welding Technology*, 1979, p. 174.
K. A. Lytle, GMAW—A Versatile Process on the Move Paper presented to the AWS Annual Meeting, Apr. 5-10, 1983, published in *Welding Journal*, Mar. 1983 issue vol. 62

FIG. 2

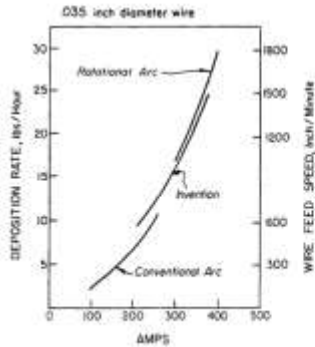
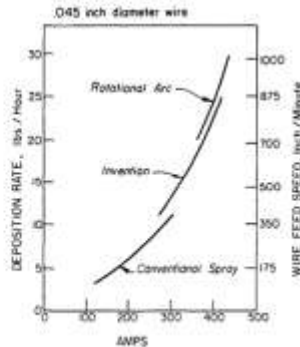


FIG. 3



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This Old Patent
has Excellent
“Teaching.”
Worth Reading IF
tying to increase
deposition rate.
Download a copy.

Gas Mix:
8% to 10% CO₂
1 to 2% O₂
Balance Argon.

A two part gas
mix can be tried:
10 to 15% CO₂
Balance Argon

This old patent has some good “teaching” re operation. Worth downloading and reviewing. Note, unlike Rotational Arc, the process was stable from as low as 10 lb/hr near the upper end of normal Spray Arc. Without the “arc rotating,” metal transfer is like a hot Spay Arc. Deposition rates as high as 25 lbs/hr were possible. However, like Rotational Arc, it is very HOT for the operator. We called the process as Hi-Dep II. The welding package included a Microprocessor MIG feeder that incorporated a ramp-up to the steady state WFS at starts and ramp-down in WFS before stopping. It was sold with what we jokingly referred to as “Cool Hand Luke” gloves. It was an aluminized outer layer foundrymen’s glove. It was needed to protect the welder’s hand from the arc radiant heat. A high current capable, 600 amps at 100% duty cycle manual, our water-cooled ST-16 was used. That torch is still sold by the current successor to US Linde’s welding business, ESAB!

If desired to evaluate for an application, suggest starting with 0.045 wire (*to achieve reasonable WFS versus the 2000 ipm max WFS system we sold with the process.*) Use a MIG gun with long nozzle, short contact tip as a longer than normal TTW is used (*water cooled gun preferred.*) Start with 1 1/8-inch TTW.

References

1. *"The Science of Arc Welding"* by C. E. Jackson. Linde Publication # 52-201 (printed 1968) Also available "The Science of Arc Welding," by C. E. Jackson; The Welding Journal, (39) (Three Parts) 129-s to 140-s; 177-s to 190-s; and 225-s to 230-s (See FootNote)
2. "Reliable GMAW Means Understanding Wire Quality Equipment And Process Variable" by KA Lytle American Welding Society Welding Journal in March 1982
3. GMAW, A Reliable Process on the Move" by K.A. Lytle American Welding Journal March 1983, Vol 62.

(FootNote) If you'd like a PDF copy of this historical, still excellent technical paper ~30 pages. Email Jerry_Uttrachi@netWelding.com

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Additional reading and videos to consider:

"Advanced Automotive Welding" by Jerry Uttrachi; 176-page book available at <http://netwelding.com/prod02.htm>

"Weld Like A Pro" by Jerry Uttrachi (another Cartech Book still available on Amazon etc.

If you would rather watch than read: These videos relate to welding math and use of an Excel Spreadsheet:

1. Welding Math Part 1: <http://www.youtube.com/watch?v=CyRwil-alZY>
2. Welding Math Part 2: <http://www.youtube.com/watch?v=1GmGdS7V24g>
3. Welding Math Deposition and Penetration:
<http://www.youtube.com/watch?v=O8zz-Nb0q9Y>
4. Welding Math Deposition and Penetration Spreadsheet:
<http://www.youtube.com/watch?v=cuAbV3FHwQw>

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About the Author



- Mr. Uttrachi has a Bachelors and Masters Degree in Mechanical Engineering and a Masters of Science Degree in Engineering Management from the New Jersey Institute of Technology.
- He started his welding career as an engineer in one of the leading welding R&D Laboratories working on the Submerged Arc and Electroslag welding processes. All of the other young engineers in the Lab were working on TIG and newly introduced MIG and Plasma welding processes. They could see the arc and weld puddle formation etc. Submerged arc and Electroslag welding processes required another approach!
- He was fortunate to work with one of the pioneers in Submerged Arc welding, Clarence Jackson whose techniques and insight became his “eyes” under the flux while welding (see Reference 1)
- An oscilloscope and oscillograph also added to this understating.
- Welding Science and Math were keys to that endeavor.

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Mr. Uttrachi has Masters Degree in Mechanical Engineering (Emphasis; Behavior of Metals) and a Masters of Science Degree in Engineering Management. In his graduate degree programs, he focused on Statistical Techniques, Metallurgy, Manufacturing Engineering and Engineering Management. Graduate courses included: 1) Advanced Analytical Engineering Statistics; 2) Statistical Inference; 3) Vector and Tensor Analysis; 4) Engineering Reliability; 5) Instrumentation; 6) Principles of Physical Metallurgy; 7) Engineering Metallurgy of Alloy Steels; 8) Light Alloys, 9) Corrosion; 10) Masters Thesis: “Effect of Weld Cooling Rate on T-1 Steel (A517) Weld Metal” 11) Managerial Economics, 12) Industrial Costing and Managerial Control; 13) Advanced Management Engineering; 14) Planning and Management of Industrial Research. His Management Master Thesis: Design of an Enterprise required preparing a 5-year business plan. His was building welded Aluminum Boats. That included facility, employment needs and costs and 5 years cash flow analysis.

He attended a number of related courses while in industry including: 1) Reliability and Maintainability (by Dorian Shannen @ AMA); 2) MRP/Costing by Ollie White (Ollie White & Associates) [*After working within the MRP manufacturing system for a number of years I now understand that this approach was based on a very poor assumption!*]; 3) MRP II (R.D. Garwood, Inc.); 4) Achieving Process Improvements Through Activity Based Analysis (National Association of Accountants); 5) Louis Allen Management System; 6) TEAM TRAINING techniques were reinforced in the following courses: a) Team Training Skills (Cornelius); b) Team Training Management Update (Don Lyttle); c) Team Skills (AWS); d) Conflict Management (AWS); 6) Quality Quest Leadership (FETCH)