WA Technology

History of Welding Linked to Capitalism!

By Jerry Uttrachi

Today's most widely used welding processes were developed in Countries with a strong competitive, capitalistic environment. There is a reason! This document is supported with many references including patents.

If only interested in documented Invention years of the welding and cutting processes and product development history, skip the following long Prologue.

Prologue:

First, why do I mention innovations occurred where capitalism and competitive environment existed? Many years ago, I wrote a detailed, extensively documented paper for a Management Master's course, essentially the final exam. In the references at the end, is a link to that original paper, significantly updated.

This paper expands on the original research. It shows why key competitors in the welding field, including Lincoln Electric, having significant differences in business philosophy, promoted competition and innovation.

I started my welding career in R&D when I graduated with a degree in Mechanical Engineering in 1964. While working, and attending in the evening, I earned a Master's in Mechanical Engineering in a specialty referred to a "Behavior of Metals." I then started a Management Masters in the Industrial Engineering Department in 1967 and earned that degree in 1969. Frankly learned more in those Master's programs because I had work experiences where I used the learned information (*for example used a partial factorial experimental design of a SAW process with many controllable variables that lead to a significant increase in welding speed for companies making gas and oil pipe.*) Also learned from my fellow students, most also working full time. A Professor could not match the fellow from P&G giving a presentation to the class about the distribution research they did to define effect on sales volume by different times to replenish stock to drug stores. They tested by purposely refilling in a day to waiting 4 days!

Or when ***"New Improved Tide"*** should be introduced. It had nothing to do with new product development, just when one of several small product differences that existed could justify extra marketing costs to increase sales volume. And when the estimated sales increase supported expenditure of marketing costs, coupons etc. Hope they learned as much from my required presentations!

I started working to develop a welding process improvement our company, Linde, developed in the mid 1930's, Submerged Arc Welding. There was a very large volume market segment where we were the sole supplier of flux and wire. Making the 40 foot long, ID and OD butt welds in 16-inch ID and larger diameter, high pressure gas and oil pipe. We had only one significant competitor, Lincoln Electric, who continually tried to enter this very high-volume market segment. Their lower product price offering, their company strength, was not effective!

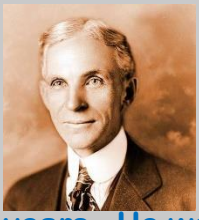
JF Lincoln:

Ohio born in 1883, JF Lincoln attended Ohio State in Electrical Engineering. He played football for 4 years and some of the unique business systems he developed had ties to football experiences. In his several excellent business management books he stated: *"Like football players, individuals cannot reach their maximum potential unless that are challenged by a coach to extend and develop their abilities past what they might believe is their maximum potential."* His very aggressive financial incentive system noted: *"Like football players you reward the best performers with the highest pay!"*

What had me read the JF Lincoln management books and become a *"student"* of the company, was something my boss showed me when I started working on SAW Process Development. It was a single page, about SAW trouble shooting, marked ***"Confidential For Lincoln Salesman Only"***. There were 10 steps that started with check the voltage, check the amperage etc. Number 10 was the key to understanding his customer philosophy. It said: *"You have spent enough time with that account, Linde (our company) can have that business!"*

Yep, Lincoln had that philosophy about his products and cost. He wanted to support the customers who bought ~80% of the welding products and leave those with special needs to others. A comparison is Holiday Inn. An acceptable place to spend the night BUT no Hilton, etc frills! His goal was to have a limited product line and continually lower manufacturing costs to lower prices. He said that was best for customers and would increase their product volumes and profit. That got me to read and often reread his business books. The last is, A ***New Approach to Industrial Economics*** written when he was 78. He ran the company until his death in 1965 at 82, still sharp as a tack. William Irrgang followed as CEO until 1986 with the same JF Lincoln manufacturing-oriented business philosophy.

Henry Ford:



In addition to Lincoln's management books, and being a car buff, also read about Henry Ford. I knew his early approach was like Lincoln's strong desire to avoid new products and to continually lower the price of existing products. Henry was improving manufacturing methods and kept the Model T design for almost 20 years. He was able to lower the price significantly with a huge increase in sales. In 1908 he offered the Model T at $950. In the Model T's 19 years of production, it dipped as low as $280 (*$4,439 in today's dollars*.) His $5/day high pay was not done to be altruistic. He understood paying workers double the going wage helped overcome the monotony of the assembly line. The high salary made them work harder and accept new methods to make cars faster! Half was called profit sharing based on a number of factors. Build time for a Model T went from 12 ½ hours to 93 minutes! Peak annual sales volume in the mid 1920's was 2 million.

Another similarity was what Henry Ford used in the early days, ***"You can have any color you want as long as it's Black***!" Continually lower the cost of existing products to gain sales. Lincoln said following a new fad takes management's attention from the main focus of lowering the cost and price of existing products.

Fred Taylor:

Taylor was known for his methods of improving Industrial efficiency. He wrote the Principles of Scientific Management in 1911.

I believe both Henry Ford and JF Lincoln must have read his work including how production workers are motivated.

Taylor's Scientific Management Principles:

1. Replace rule-of-thumb work methods with those based on scientific task study.
2. Scientifically select, train and develop each employee rather than passively leaving them to train themselves.
3. Provide detailed instructions and supervision of each worker in performance of their discreate task.
4. Divide work nearly equally between managers and workers, so the managers apply scientific management principles to planning the work and workers perform the tasks.

Taylor was so successful promoting his scientific system, Congress in 1912 had a special committee investigate some say he was "pushing" workers to excess! I read the many volume records! Congress then passed a Law that said no government facility was allowed to use "time study!" Rescinded only in 1950s!

JF Lincoln's ideas:

JF Lincoln developed a similar approach to Henry Ford. He wrote: "Following the *"will-of-the-wisp"* new products the sales folks want because they think it has higher profits, takes management focus away from lowering the price on existing products, which is best for the customer. He pressured his folks to eliminate a product IF a new one was needed or desired. They kept the number of salable goods very low with no inventory or even spare parts held in the factory. All were shipped to >30 district office warehouses based on what they forecast. District managers were expected to sell what they forecast and ordered!

He wrote, if your business expertise is being a low-cost manufacturer follow that philosophy. If it's R&D developing new products you should pursue that approach. That latter fit our corporate company culture and some others like AIRCO our industrial gas competitor, also in the welding business. Neither were, nor tried to be, low-cost manufacturers of welding related processes or products. Both were introducing new welding products and processes (*most used industrial gas.*) Some, like TIG welding had many variant air and water cooled torches in many lengths. Also, collets, collet bodies, gas lens etc to fit the torches for various diameter tungsten electrodes. Lincoln would not think of offering TIG torches, partly that they used gas and also, they required hundreds of part numbers, in total opposition to his manufacturing simplicity concepts. Was not until the 1990's that they introduced TIG torches (*outsourced as they are today.)* Frankly we and AIRCO made the vast majority of our profit selling Industaial Gas (Oxygen, Nitrogen, Argon and Acetylene.) Also filling and renting high pressure gas cylinders. Welding was mostly a tool to support gas sales.

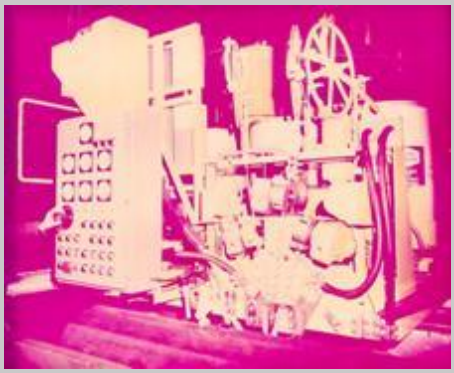
We all coexisted during the era of significant welding process and product development. The competition with different businesses philosophy, goals and methods created innovation!

In the mid 1970's I managed a filler materials and MIG/TIG welding gases R&D Lab for Linde in Ohio. We were also responsible for SAW and Electroslag process development. Some Lincoln hourly worders were making more than I as LAB Manager! The Cleveland paper had stories of some earning a total compensation of ~$100,000 in years where the annual bonus was ~100% of salary (*% of salary bonus was based on how the company did.*) That took beating their production piece rate and working a lot of overtime.

JF Lincoln understood workers would not come up with better, faster work ideas if they thought they might work themselves out of a job. So, he guaranteed a 30-hour work week if you were employed for over 3 years. No layoffs BUT you were expected to work overtime, including weekends when times were good, so the company did not have to hire more folks!

I recommend reading JF Lincoln's books as well as a book by the former CEO (*see references*) who became a friend when we both retired and served on the American Welding Society's Foundation Board. Don Hastings was a Lincoln Salesman, District Manager, VP Sales, President then CEO during the time we were competitors.

One fun anecdote was when rereading one of Lincoln's Books at the Cleveland Airport. The then President of Lincoln, George Willis came over to my seat and said young man (*I was ~35, he ~55*) you know that book you are reading was written by our company founder. I said sure do and introduced myself. He was with a VP, Al Patnik, and introduced him to me. Mr. Patnik said, "***I know him; he is who I follow at all the Pipemills!"*** At the time we had 100% of the SAW flux business in the ~9 US large diameter, UOE high pressure gas and oil pipemills, most owned by steel mills. I had invented a 3-electrode, 3000 total amp system that doubled prior production speeds. It was being used by many of the mills. Pic left is one of 8 of our 3-Wire Systems Installed at the US Steel Pipemill in Provo Utah. There were well over 100 systems installed in the US, Canada, Mexico, UK, South America, Iran, Italy, and Japan. Around that time, ~half the fused flux we produced was shipped to those mills in truck load quantities. It sold for a 30% premium over Lincoln bonded flux (*and cost us half of what our bonded flux cost to produce*.) Very profitable! I frequently visited all the mills with our Regional Sales and Engineering folks. Hasting and I talked about that market when we were both volunteer members of the AWS Foundation Board. He lamented that they did not have fused flux, only bonded. Never told Don that was NOT the reason we had 100% of the business!

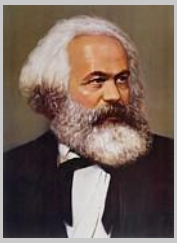


SIDEBAR:

Of interest, this is what Don Hastings states in his book, ***Behind the Mask,*** about Al Patnik, when Don was promoted to General Sales Manager, quoting: "*Al reported directly to Irrgang (CEO) I always felt a little like he was spying on me. Al reminded me more of a spy satellite than part of my team. So more often than not, I simply ignored him. Since I couldn't beat the system, I forced myself to work within it. What a stupid situation!"* Yep, there were a number of flaws in the Lincoln system. I uncovered many in my extensive efforts to find things about their secretive operations! Interviewed hourly workers who left working in Cleveland!

Communism was the total opposite of our competitive capitalism with its aggressive efforts creating innovation to get ahead of the competition. Some like our company used R&D and new products. Others like Lincoln and some others, (*like parts copiers*) used lowering manufacturing cost and product price. TIG torches, collets, collet bodies and gas cutting nozzles come to mind.

Karl Marx:



I traveled about 25% of my time. Supported our Regional sales and engineering folks with large fabricators. No Internet, no cell phones a lot of airplane travel time to read and think through possible competitor actions. In addition to rereading JF Lincoln's business books recall removing the cover of a thick paperback bio of Karl Marx! (*Didn't want folks who might see me thinking I was a communist! LOL*) His philosophy of ***"Work according to your ability and be paid only to your need"*** is the opposite of human nature. As Taylor showed in his coal shoveling incentive pay example, when his best workers left to go with a competitor, they went from individual output measure to a group incentive. Their output deteriorated to that of the slowest worker. Or what JF Lincoln expounded and practiced, pay folks according to their output! Lincoln's system measured that accurately per individual. Hourly workers saw their piece rate output daily.

Of interest, a French newspaper reporter interviewed Marx and said he lived in squaller. Worse was his body was covered with boils and solidified puss was on the chair he sat on! It has recently been found that Marx suffered from a skin disease that can cause severe psychological effects such as self-loathing and alienation! "The father of communism's life and attitudes were shaped by hidradenitis suppurativa," said Sam Shuster in the British Journal of Dermatology. One symptom is alienation - a concept that Marx, a martyr to boils and carbuncles, put into words as he wrote Das Kapital. The condition was described in 1839 by French physician. Nina Goad, of the British Association of Dermatologists, saying: "It is fascinating to discover that such an influential figure suffered from hidradenitis, especially considering how it might have affected his ideas.

My Personal Experiences

In addition to my observations about how capitalism promoted competition and innovation I have personal experiences where the opposite became obviously the wrong incentive. I'll relay a few:

1. When I started college, probably like many, I saw democracy was a messy way to get "needed" things done. Thought Franco in Spain appeared to be a benevolent dictator in his fascist regime. Soon leaned to maintain his power required corruption and reduction of individual freedoms.
2. An incident with a "street hot dog vendor" while going to college in the evening, caused me to think about the errors in our methods in trying to help poorer folks. Fellow who owned the cart was an immigrant from Europe. Appreciated his entrepreneur spirit and hard work.

Was little time for "dinner" before classes, two hot dogs with his grilled peppers and onions were fine. One evening his friend came and complained that he was living in a government supplied apartment and his wife was expecting another child. He had a daughter, and this was a boy. He said he is only allowed two bedrooms and did not want the boy and girl to sleep together as they got older. My then friend, who was smart, we'd discuss getting a 2nd cart and hiring a person to operate, had a simple solution. All you have to do is have another child and you will be "given" another bedroom! Thought, the fault with this logic is we have created the wrong incentives! Having more children should not be done to get more food stamps.

3. On a visit in the early 1970's supporting our Linde welding company in Germany visited with a fixture house. The owner was selling a large SAW system to Russia. During the conversation, from his experience in WWII, he hated Russians. I asked if he felt bad helping the Russians with these equipment systems. He laughed. He said this equipment is being bought by the central control folks in Moscow for a plant far from where they are located. By the time it gets there many of the smaller parts will be stolen. I will get orders for all the small parts like the welding wire feed motors and controls. If they get all the parts to rebuild, the plant probably has no use for the equipment and wonders why it was bought for them!
4. In the mid 1970's we had an exchange with the Paton Welding Institute in the Ukraine. It was arranged with the help of the State Department as relationships with Russia were "improving." We had our first visit to our filler materials R&D Lab and a CIA rep visited to let me know of the 5 "scientist" who were coming which was the KGB Agent and questions he would ask. Never said what I could tell him as most were ones I did not know, like where do you get power and what is the Kilowatt output. He said he is required to report those things. You can just tell him what you know, which in most cases you'll have no idea. No problem for him, he'll put in some values! On their next, and last visit the CIA agent came again and said during the last visit they were convinced you took them to the Mayor's house for dinner as it was so nice. It was a moderate home owned by our business manager! So, I picked up the two "scientists" (*one the same identified before as the KGB agent*) including the bright young institute engineer. It was Sunday so for lunch brought them to McDonalds and emphasized this is where the average person eats!

The young scientist asked what the pay difference was between an Engineer and Technician. I thought and said considering the higher percent taxes paid for the somewhat higher engineer's salary and no overtime pay versus the technician, I'd said about 20%. I asked what it was at the Paton Institute. He said, "Oh can't compare." For example, for my wife and child we can rent an apartment. Not available for my Technician, he and his wife live with his parents. I can get a car, might take a year, he cannot, must buy a used car. He asked about appliance prices, and I gave some estimates. I asked how much a refrigerator costs. He said, now they are very cheap because the central committee folks way overbuilt. But a washing machine is not available as they forecast way too few. That prompted a contentious conversation in Ukrainian between he and the KGB Agent! The scientist was obviously not happy with Communism!

5. The last relates to that visit from the Paton Institute in the Ukraine. It involved the technician I hired when our Lab was in NY. He was Cuban refugee who managed to escape with his mother. His father was still in Cuba. He hated the Russians for what he felt they did in Cuba. His father had a farm that was taken over by the Communists and was "given" to the Communist Major of that town. His father worked in the fields. Prior to the Paton tour, as usual I went through the Lab asking to see the planned demonstrations. This fellow was supposed to demonstrate a new flux cored wire. He was so upset and said he hated Russians so much he hoped he could remain calm. Told him to take the day off and I'd have another make his demonstration.

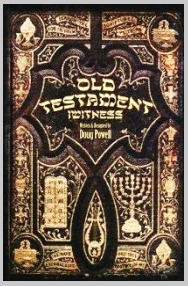
BTW, in 1980, what was called the *"Flotilla"* there was a mass exodus of folks from Cuba this technician, who then had a field engineering position, was given a month off as he with friends chartered a 35-foot boat and took folks from Cuba to Miami. Although their boat did not get his father, another did. They are all now living in Florida.

The following covers the most significant welding (and cutting) processes introduction. There are many others NOT COVERED like Resistance Welding, Laser, Electron Beam and more.

The AWS designation is in Brackets following the more common name.

Key Modern Welding Processes Invented

Forge Welding (FOW)



Welding is not new. Tubal-Cain is a person mentioned in the Bible, Genesis 4:22, known for being the first blacksmith. He is described as the "forger of all instruments of bronze and iron."

Note forging does not melt the materials but makes them sufficiently hot that with pressure is applied they weld.

Oxyacetylene Welding (OAW & OAC)

In 1892 Morehead and Wilson accidentally discovered how to make acetylene. It was found that combining acetylene with oxygen produced the hottest known flame temperature. Morehead (Photo Left) went on to found one of the world's leading chemical companies, Union Carbide. In 1917 Union Carbide merged with the US owned Linde Air Products company started by Carl von Linde in 1907 using his process of separating air by liquefaction and distillation. The combination of acetylene and oxygen produced a concentrated flame with a temperature of 5720 F, well above the melting point of most metals allowing the oxyacetylene welding process to develop into a leading metal joining technique. In addition to marketing industrial gases in cylinders, Linde developed the required regulators, torches and accessories needed for the oxyacetylene welding and cutting process. Their trade names were Oxweld, Purox and Prest-O-lite.

The Canadian by the name of **Thomas Willson**, became known as Thomas "Carbide" Willson, for his discovery of the inexpensive method for manufacturing Acetylene Gas.

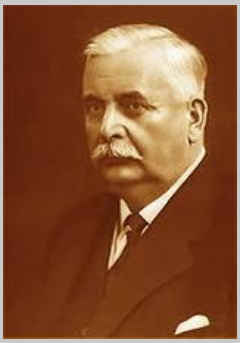
Union Carbide was formed to underwrite the development of uses of calcium carbide. Around the world, demand for carbide outstripped supply, especially as acetylene lighting was installed in streets and buildings.

Of interest, Butch Sosnin, AWS Past President (1977/78) was a very skilled welder trainer among his other welding related knowledge. He was a consultant for Linde for many years. When asked to train stick welders for a power company he insisted they start with oxyacetylene first because it was slow, and you could see the weld puddle develop. He then wanted them to practice TIG welding as although faster and the weld puddle developed quickly you could again clearly see the leading puddle edge. As he noted, only then were you ready to learn Stick welding where watching the leading puddle edge was not as easy as things moved quickly, and fumes reduced visibility. Others agree with that learning approach.

Stick Welding and Stick Power (SMAW)

Electrodes:

In 1890, C.L. Coffin of Detroit received the first U.S. patent for an arc welding process using a metal electrode. This was the first record of the metal melted from the electrode carried across the arc to deposit filler metal in the joint to make a weld.



In 1904 Oscar Kjellberg in Sweden (*the founder of ESAB, Pic left*) patented the covered electrode. This electric welding process electrode produced excellent quality, strong welds very fast. ESAB became a world leading enterprise supplying welding equipment, filler materials and welding technology. They purchased AIRCO's electric welding equipment business in 1985 and in 1989 Linde's (*subsequently renamed Praxair)* former welding/cutting equipment and filler metals business, which had become a separate company, L-TEC. At the same time, they purchased the leading US innovator of flux cored wire and low hydrogen stick electrodes, Alloy Rods.

Power:

In 1911, Lincoln Electric introduced the first variable voltage, single operator, portable welding machine in the world. In 1914, JF Lincoln then President of the company, established the Employee Advisory Board, which included elected representatives from every department. His incentive management system helped Lincoln become a leading producer of electric welding equipment and filler materials. They were instrumental in promoting welding as a reliable, cost-effective metal joining process.

The unique management system employed by JF Lincoln had an influence on the development of welding history.

Electric Welding competed with Oxyacetylene welding. Probably one reason JF Lincoln wanted nothing to do with processes that used gas. They did not introduce the first MIG welder that used gas until late in Bill Irrgang's CEO term that ended in 1986. Irrgang followed JF Lincoln's low-cost manufacturing ideas including keeping the product line small and simplified.

Irrgang also had an aversion to anything to do with gas. It's reported part of his opinion was a poor relationship issue with Big Three of Texas in Scotland. I recall when giving an AWS talk in the late 1970's where the Lincoln District Manager was the local Section Chair. He relayed that George Willis (President), and Bill Irrgang (CEO) were at their District sales meeting the day before. A salesperson had mentioned MIG welding. George Willis (*who was very tall*) stood up and said, ***"Mr. Irrgang said if anyone feels the need to use the word MIG again they can leave now!"*** Irrgang remained CEO until 1986.

For Use With Innershield Only—

Warranty Void iF Shielding GAS Is Used!

Another funny incident occurred in the early 1980s. It was at an AISC Conference with a small exhibition where I helped staff our Linde booth. When lectures were being conducted the exhibitions were closed. I went over to the Lincoln Booth to see what they were showing. That has always been my MO, to be friendly with the competition. Did the same when competitors came to our booth. Would tell them what I would a customer. In this case it was my first view of their self-contained wire feeder and power, the SP200 as I recall. . It did NOT have a gas control solenoid as it was designed to work with their "no gas" flux cored wire called Innershield. The Lincoln salesman pointed out the Warning Label inside. It said this welder is not designed for use with gas shielding products. If used it will void the warranty! He laughed and as long as Irrgang was not there, he was safe!

Yep, no love lost between Lincoln and the Industrial Gas companies! It prompted Lincoln to work very hard to produce a flux cored wire that did not need gas! Don Hastings is quoted in a book by Virgina Dawson: ***"The failure of Lincoln to make machines for gas shielding allowed Miller, Hobart and L-TEC to enter the market creating fierce competition that could have been thwarted had Irrgang allow development of gas-shielded machines!"*** (*page 124, see References.*)

SIDEBAR

The aversion to make products that used Industrial Gas probably stems from JF Lincoln and was carried thru by his successor after his death in 1965 by Bill Irrgang who was CEO until 1986. It was probably influenced by the early 1900rds competition between gas welding and electric welding mostly stick welding, where Lincoln had a high market share with inexpensive products.

It may also have been influenced by his belief that improving production and products to make them cheaper was the "Christian Thing To Do." Quoting JF Lincoln: "The Christian ethic should control our acts. If it did control our acts, the savings in the cost of distribution would be tremendous…Competition, then, would be in improving the quality of products and increasing efficiency in producing and distributing them; not in deception, as is now too customary."

Lincoln was no doubt aware of the monopolistic practices of the Industrial Gas Business. Being an oligopoly, prices were always increasing and controlled by long term contracts, the few competitors would not break. Cylinders had to be rented (though JF Lincoln's death in 1965 even small cylinders were rented and distributors nor manufactures would fill an owned cylinder.) Charley Sanborn reinforced what Don Hastings mentioned and Lincoln wrote about distributors. Sanborn owned auto stores in Ashtabula OH where I worked for 6 years. It was an era where they rebuilt engines etc. He wanted to distribute Lincoln welders and electrodes. He visited JF Lincoln and came away with "he didn't see a need for distributors!" Lincoln felt distributors should buy in big quantities and sell to users at MSRP. He was only giving distributors a ~5% discount on 40,000 lb truck load quantities of electrodes, for example.

One additional anecdote was the Lincoln engineers working on a flux cored wire that needed no gas came to him with a solution, but it used CO2. When they told Lincoln he reportedly said, "If I wanted a welding wire that used gas, I would have asked for that!"

It's good to understand gas industry economies and profits. When Director of Welding Market Development in Linde's Corporate Office my group was funded 2/3 by gases, mostly Argon profits. At that time, we had ~60% of the US and Canada Argon production capacity. We sold about half, our overall gases market share and the remainder to the few other major Industrial Gas Competitors at wholesale prices - we controlled the market price!

I developed an arrangement with Unimation to help them promote arc welding robots. What was humorous to me is Lincoln was promoting Innershield as usual turning a disadvantage into a benefit. Innershield has low penetration. Lincoln turned that around to "it bridges gaps!"

Innershield required "long stick out" that was a key cause of the low penetration. (I referred to the "long stick out" as bake your own!) Most making gas shielded flux cored wire understood you had to bake the wire close to finished drawn size as drawing lubricant entered the seam.) Lincoln did not bake and with shorter than their required "long stick out" you could get hydrogen porosity or what were called worm tracks in flux cored wire welding where evolving gas was trapped between the solidifying weld metal and slag. May have been other reasons for the long stickout such as overall performance.

Gas shielded solid wire MIG made far better appearing and low spatter welds. The Unimation arrangement was each of our six regional sales offices got a Unimation Robot to demonstrate to potential customers. The profit for Linde was not selling Robots, that was the Unimation's sales reps' function and their profits. Making the profit potential calculations the major benefit for Linde was NOT the completive solid or gas shielding flux cored wire sales or certainly the one-time sale of equipment. By far the most profit came from ongoing Argon shielding gas sales! Our Sales Region Objective was to get an Argon gas multiyear contract signed for making samples etc. Air Products had done that with Nitrogen for food freezing! For them to show you their "proprietary" food freezing technology or provide samples all you had to do was sign a 3 year "Nitrogen Use" contract IF you used it for food freezing! Was easy as most folks would sign as they had no other potential use for Nitrogen.

From my study of Lincoln Electric through Irrgang being CEO in 1986, I believe understanding the high oligopoly pricing practices of the Industrial gas business was a factor in their aversion to gas using processes. If JF Lincoln or Irrgang were alive today where ~75% of the North American Argon production is held by two foreign companies (Air Liquide who bought Airgas, German Linde AG who merged with US Linde renamed Praxair) and seen the Argon price increases, it would just reinforce their belief! Messer Griesheim another German gas producer recently entered the US gas market and Japan Oxygen (Matherson Tri-gas in the US) has been here for years. All just follow price increases!

Yep, even today many large fabricators don't understand they are using (*because of waste)* over 3 times the amount of Argon based shielding gas they should. They don't see the waste, and most don't calculate what they can save. That is my current business! With simple, no moving parts patented products where welders see and appreciate the weld start benefits the average reported shielding gas savings is half their former use!

Touring one of their 10 fabricating plants, a VP would toss quarters on the ground welders scurried to pick up. The plant manager, conducting the tour, would ask, *"What are you doing?"* He'd say, *"That is what you're doing every day - wasting shielding gas!"*

Submerged Arc Welding (SAW)

Some quote the Robinoff patent as the "invention" of Submerged Arc. A careful review will show it was not! The patent, number 1,782,316, was filed in May of 1929. The patent Specification shows a relatively small amount of flux (*by Submerged Arc Welding practice*) being applied in the joint. Further on Page 1, Lines 40 to 44 in the Specification it states: "The groove is then filled with a powdered scale (ferrous oxide) to make the flux magnetizable." It states, "…the welding current will flow …through the rod and will become magnetized so as to attract the flux. Their final claim, number 8 states; "…*moving the metal electrode … and drawing an arc causing said flux to melt…*" IF this were truly a Submerged Arc Welding, they would have the same difficulty as the inventors, i.e., Kennedy et all in defining if there was an arc and would have at least not mentioned the presence of one! However, no doubt since there could be questions raised in any patent litigation, Linde purchased the rights to this patent as well as those that were significant. R.D. Simonson, in his book "The History of Welding" states; "*Then the Western Pipe and Steel Company called (referring to Harry Kennedy) for help with its Robinoff welding process. Kennedy's notes indicate that the problem there was attacked through the welding flux being used. It soon became apparent this was no minor problem, but one which, if it could be solved, would lead to the development of a basic new welding process. Simonson further states on page 141; "Thus when the business relationship between Kennedy and the Western Pipe and Steel Company became mutually unsatisfactory in the early thirties the way was open for the Linde Air Products Company to enter the picture. Linde's recognition of the value of the process at this early stag*

The key patent that defines the Submerged Arc process is US Patent number 2,043,960 by Jones, Kennedy and Rothermund. This patent was assigned to Linde and filed in October 1935. The Specification states, that the application was in part a continuation of applications Serial Numbers 657,836 and 705,893 filed in February 1933 and January 1934.

Patented June 9, 1936 2,043,960

UNITED STATES PATENT OFFICE

2,043,960

ELECTRIC WELDING

Lloyd Theodore Jones, Harry Edward Kennedy, and Maynard Arthur Rothermund, Berkeley, Calif., assignors, by mesne assignments, to Union Carbide and Carbon Corporation, a corporation of New York

No Drawing. Application October 9, 1935, Serial No. 44,143

29 Claims. (Cl. 219—12)

This invention relates to electric welding. Among the various ways in which electrical energy has been converted into heat for the welding

to necessary to successful welding unless compensatory means are resorted to. These diffi-

There are no other patents sited against or referenced in US Patent 2,043,960, indicating this basic process and flux patent did not need to refer to that by Robinoff.

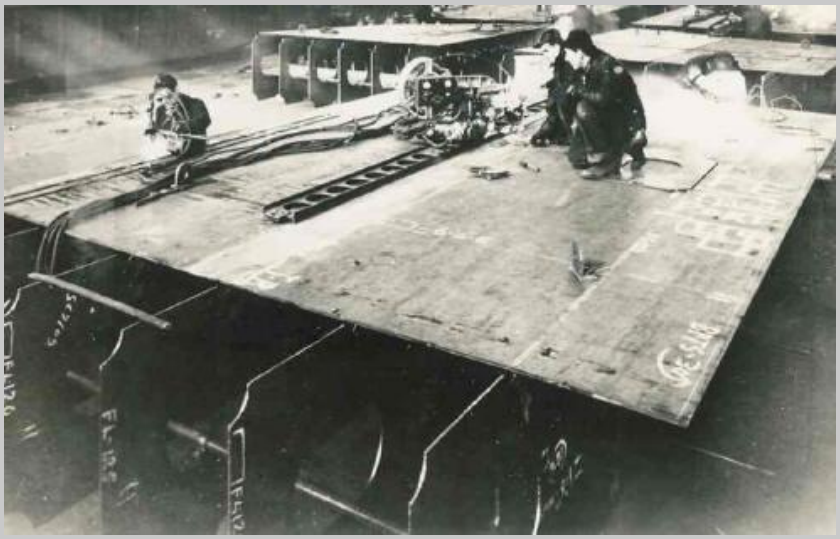
The Specification further discusses what is no doubt the Robinoff "process" namely quoting: ***"There is another known means of applying protective flux. It consists in utilizing thick coating of finely divided material, a flux, which covers the weld seam. The following is a typical analysis of such a flux…4.34% Fe_2O_3…3% Fe. … Moreover, the vigor of the arc submerged under this flux projects a continuous cloud of material into the atmosphere. As evidence of the amount of gas that is emitted by a flux…welders frequently wear gas masks…it is not surprising gas holes should be found in the metal of the weld."***

Quoting the main uniqueness of the process in the Specification, ***"We have discovered a novel process for electric welding wherein the necessary heat is generally by the passage of a heavy electric current between the metal electrode (usually bare) and the… objects to be welded…the current being carried across the gap between the electrode and the objects by and through a conductive melt or welding composition having appropriate electrical resistive properties. … The welding composition serves as an active instrumentality, or welding media inasmuch as it provides heating means, controls the rate of penetration and quality of welding, purifies the molten metal and protects the molten metal."***

They also define a need for prefusing the flux ingredients in the Specification; ***"The chemical reactions between the components of the welding composition must be completed before it is used in welding. Failure in this regard most surely invites porosity."***

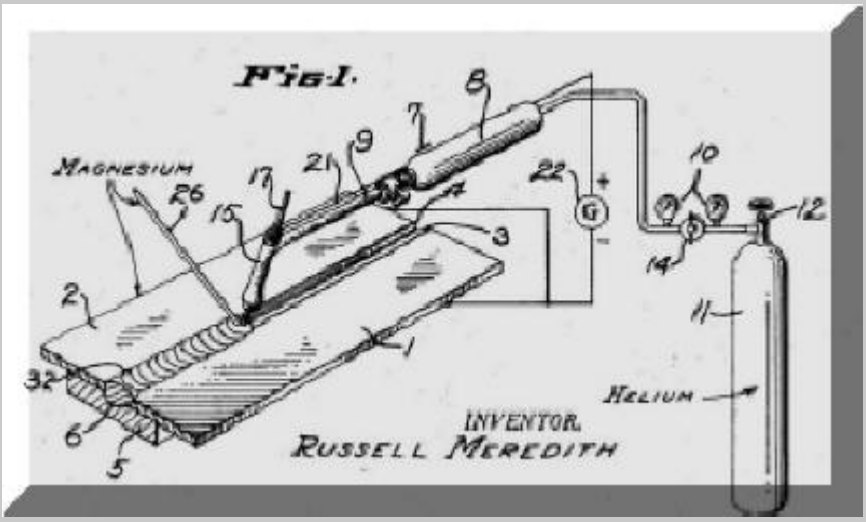
The patent further defines at least 4 compositions for fluxes including a preferred method of manufacture.

SAW was widely used in WWII to build ships, tanks, trucks and other weapons of war.



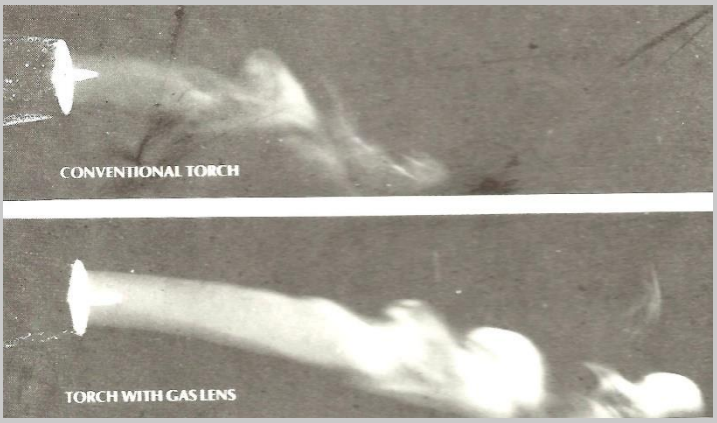
TIG Welding (GTAW)

Russell Meredith, working for Northrop Aircraft, was the first to produce a system that was a true production tool applying for a patent in January 1941 (US Patent # 2,274,631, Figure 1 left.) He was concerned about meeting a critical national need of welding light weight aircraft materials. In the first line of the patent, it states, *"My invention relates to welding magnesium and its alloys - - so relatively low melting point materials may be efficiently welded by an electric arc."* He goes on to say that airplanes are being made of lighter materials and a more efficient method of joining these materials is needed.



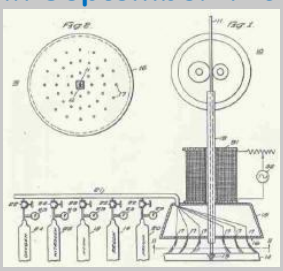
Northrup's business was building airplanes not making welding torches and all the accessories required. They sold the patent and the registered name Heliarc to Linde. Linde's interest was the Helium and Argon gas the process used. They put a lot of engineering and manufacturing effort into developing the many air- and water-cooled torches required to expand the use of the TIG process.

When I started in R&D I shared an office with the engineer who had the original patents on TIG Gas Lens, Gene Gorman. Gene conducted many tests with various shapes to produce a superior laminar gas shield that avoids air being pulled into the gas stream. He found a stakes series of very fine mesh screens did the best job. In fact, he tried and showed data in hos patent that a porous material used for a gas lens did not work because exited at various angles and promoted turbulence. A leading welding company recently introduced what Gene's paten shows does not work! Yep, being in the gas business we did know gas flow!



MIG Welding (GMAW)

A number of patents are sited as defining the Mig Process. A patent filed by Brace in September 1936, assigned to General Electric (Patent Number 2,053,417, pic



left) shows what could be said to be the MIG welding process. He defines the use of a number of shielding gases. Gorman in TIG Gas Lens patent discusses how his research using porous diffusers worked like a shower head and pulled air into the area between the streams! Also, the gas mixtures defined by Brace, although broad, may not have been appropriate for good arc stability. One can tell the metal transfer was not very good by the electric coil shown surrounding the wire in the figure. Brace states: *"I have found that the magnetic flux produced by the winding 31 when energized with an alternating-current source sufficiently disrupts the surface tension which would otherwise be present to cause the formation of relatively large globules of the molten metal from the welding electrode 11."* A complex way to achieve what would be simply controlled with the proper power supply characteristics and shielding gas mixtures!

Many acknowledge the first practical MIG system was defined in Patent Number 2,504,868 filed by Al Muller, Glen Gibson and Nelson Anderson in January of 1949, assigned to Airco. Their 16-page Specification is excellent and describes fully how the process works. Some of their claims are very interesting:

In Claims 8, 9, 11 and 12 they refer to the shielding gas being, "***non-turbulent*** to exclude air from the arc."*(Perhaps we have forgotten this early knowledge when excess shielding gas flow rates are set or high gas surge at the weld start is accepted!)* In Claim 10 they define the shielding gas as being helium or argon and mixtures of carbon monoxide and carbon dioxide. (*For safety reasons it should NOT be used!)*

In Claim 8 they define the metal transfer means as being, "a spray of fine discrete droplets within the gas shield." This was the transfer mode employed until the next major breakthrough, short circuiting MIG, or "Short Arc" as it's often called.

(Note, although there are some others occasionally credited with "inventing" MIG welding, a check of the prior patents sited in the "Gibson et al" patent assigned to Airco, # 2,504,868, such as the Harry Kennedy patent assigned to the Linde Air Products Company, show it and the others referred to equipment items for submerged arc welding or an oxy-electric cutting torch -NOT gas shielded MIG welding. The US Government grants patents to inventors to teach others science. That is why they are given a 20-year monopoly!

Flux Cored Wire:

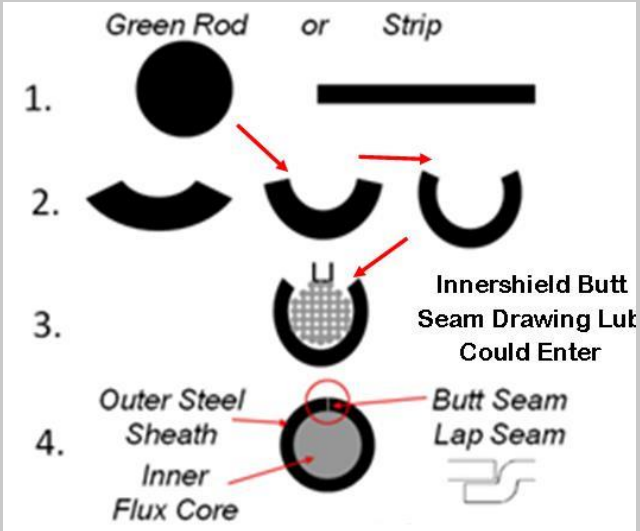
A variation of MIG welding with a solid electrode utilizing a special electrode wire was developed. In 1947. Arthur A. Bernard founded Engineered Welding Products on the south side of Chicago. What began as a small storefront quickly evolved into a strong growing company. In 1954 he invented and patented Dual Shielded welding, otherwise known as flux-cored arc welding.

United States Patent Office Patent number 2,785,285 Composite Welding Electrode by Arthur A. Bernard, Chicago, Ill., assignor to National Cylinder Gas Company, Chicago, Ill.,

Innershield: **In 1959 an inside-outside electrode was produced by Lincoln Electric. It did not require external gas shielding. The absence of shielding gas gave the process popularity for outdoor less critical work.**

SIDEBAR

Typical of Lincoln, not only was Innershield an innovation they also found a way to make the product from cheaper redraw rod. Those of us making gas shielded flux cored used more expensive slit strip. They used a type of spheroidizing heat treatment of the rod, probably done by the steel mill.



Abstracted From Lincoln Electric Document. Innershield (Red Arrows) was made from cheaper Greed Rod. But some Outershield was made from more expensive strip. It mentioned some seamless cored wire is copper coated.

SIDEBAR: *In 1964 when I started in R&D for Linde I worked on our 1st flux cored wire, FC-72. It was made from copper coated strip with a lap seam! Great product. When drawing to a smaller size drawring lubricant did not enter the seam!*

However, from macro/micro examination of their wire, the butt seam did not appear to be as tight as what we were achieving. As good as our fill and seam closer was, we still had to bake our finished product to eliminate drawing lubricate outgassing creating what are called worm tracks, gas trapped between the solidifying weld and slag left what looked like the name.

One easy test was to take a ~3-foot piece of wire and place it on stick welder terminals set with low current. It outgassed before turning red! Subjecting Innershield to that test showed it was outgassing! From observation they did not bake the product but required a "long stick out." I referred to that as *"bake yourself"* before the hot wire got to the arc! May be other reasons for the long stickout!

Plasma Welding and Cutting (PAW & PAC)

On July 26, 1955, Robert Gage (*my old boss at the Linde Labs*) filed US Patent Number 2,806,124 for Plasma, entitled "Arc Torch and Process." This was the first Plasma Torch and Process patent. It had 29 claims and was assigned to Linde. One of the patent figures is shown on the left. Although usable for welding it has gained wide acceptance as the process of choice for thermal cutting.
Bob Gage, photo right, was a brilliant Physicist and a great boss. Although tough, he always made you think, often with a critical statement such as; ***"You're solving a problem not known to exist using a method known not to work!"*** Bob managed Welding and Cutting R&D for the Linde (*in all US welding/cutting facilities*) for many years.

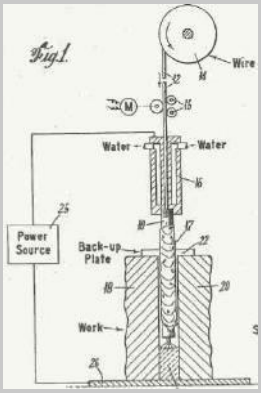
Cutting: PAC: Being in the Industrial Gas business our focus was on large, high current capacity plasma cutting torches that were used on our own CNC cutting machines. They consumed high volumes of Nitrogen and also Oxygen. We had a high market share in large oxyfuel cutting machines and Plasma cutting increased the product line strength. We designed and built our own CNC controls.

Welding: PAW: We also had a variety of Plasma Welding Systems. From the small system called "Needle Arc" that uses 110-volt input and could weld very thin materials to high current machine torches in the 400-amp range. Recall a lot of work was done in our LAB in the late 1960's on Plasma Keyhole welding where sufficient current was used to "blow a small hole" in the joint to be welded that with the right parameters the molten metal coalesced behind the torch forming a top and bottom weld. However, when we formed L-TEC in 1985 an objective was to improve production efficiency and eliminate low volume products. Many, because of the low volume had increased significantly in cost. Recall the high current Plasma Welding Torch was one. Turned out the dominate sales were to our L-TEC company in Germany. When I visited, I asked why they sold so many. They showed me in their Lab. It was not for Plasma Keyhole Welding it was more glorified TIG welding with essentially a pilot starting arc. In some cases, the electrode was almost outside the large orifice in the Nozzle. But they were buying enough to keep it in the line and were told they would have to keep stock as we were going to keep a low/no inventory.

Also had convinced them to use our Plasma Cutting Torches and stop their own production of what were inferior products. BUT they met the very restrictive German safety rules for manual cutting torches. We modified our top seller of that capacity they use to meet the German "finger" test!

Electroslag Welding (ESW)

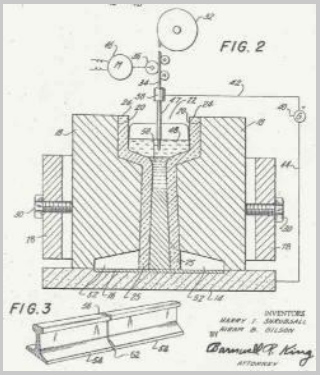
Some references site Robert Hopkins for having invented the Electroslag welding process in the 1930's. Most of his patents relate to Electroslag melting for ingot manufacture, not welding. However, one US patent, number 2,191481 filed in June 1939 does describe the surfacing of one material on another. The illustration, however, is a melting furnace rather than welding. In fact, the fellow who invented Submerged Arc Welding, Harry Kennedy, was granted a US patent in October of 1950, number 2,631,344, assigned to Linde that more closely related to Electroslag welding. However, it too falls short of defining what we know today as this simple welding process.



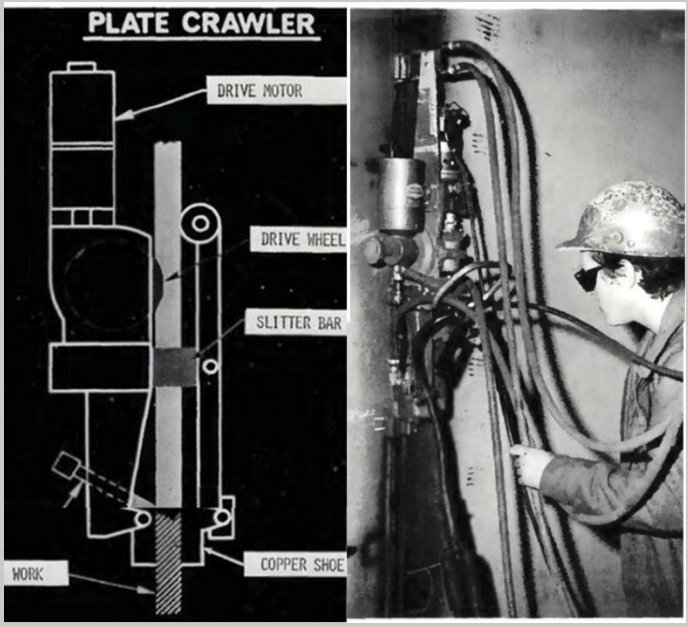
A unique version of the Consumable Guide Electroslag Welding Process was developed and patented (US Patent Number 2,868,951 filed in March 1957) by a colleague, Harry Shrubsall. The figure on the left is from that patent. It clearly shows the process as it is known today. Harry's patent includes the use of a flux coated tube to replace part of the flux that plates out on the copper molds. It also insulates the metal guide tube from the work. In the US far more welds were made with the simple consumable guide process than "conventional Electroslag" with moving shoes, etc. Several hundred thousand feet of welds were made for the Bank of America Headquarters building in San Franciso, a similar amount for the Sears Tower in Chicago and the John Hancock Building. Similar large amounts were used for bridge beam splices, etc.

The Paton Institute in Russia published a book, "Electroslag Welding" in 1959 with an English translation published by The American Welding Society in 1962. Harry Shrubsall's patent application preceded even the Russian version of the book but their work with the moving copper shoe process predates the book.

Harry Shrubsall and I worked as engineers in the Linde Development Labs (although I started after his invention!). Harry had several subsequent patents on the use of the process to butt weld Railroad Rails. Patent numbers 3,192,356 and 3,291,955 filed on September 1962 and February 1963 respectively describe Railroad Rail welding with Consumable Guide Electroslag.



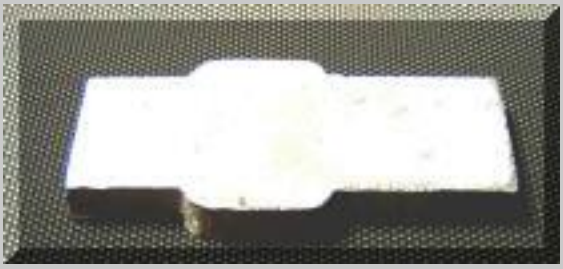
I worked on a Plate Electrode Electroslag Welding development with Harry, It used a triangular shaped electrode with two holes that spread two electrodes at the bottom to weld the Rail Base then narrowed them to weld through the Rail Web and the Rail Head on top. Welds were excellent and passed all required Railroad tests. The resulting welds were far better quality than the Thermite deposits often employed but did take longer to make. This extra time ultimately caused resistance to its use. If a train happens to be coming down the track, all workers want to be able to move fast! Can't blame them.



Two of my patents are for a metal cored wire of a specific chemical composition (patents # 3,778,587 # 3,854,028) entitled "High Speed Electroslag Welding." One defines welding parameters and slag control procedures that allowed Electroslag welding at travel speeds up to 10 ipm. The weldable plate thickness range is from 3/8 to 2 inches An article published in the AWS Welding Journal (Pic left) defined the product and application in National Steel And Shipbuilding shipyard in San Diego California.

Aluminum Electroslag Welding

In the late 1960's we developed procedures to make Electroslag welds in Aluminum. It was never commercialized. I had some weld samples (left.) In ~2005 a Canadian Company making parts for aluminum pot lines, in conjunction with Bechtel Engineering and Construction who had a large project in Iceland and my consulting produced a viable system.



The required welds for the EC aluminum Busbars were 12 inches thick and 3 foot high.

Using information from the late 1960's we knew to cover the 12-inch width would require a minimum of 5 electrodes. Special graphite shoes would retain the molten aluminum.

The flux must be lighter than aluminum leaving out most oxides used for submerged arc of Steel Electroslag fluxes. We used fluorides and chlorides.

We had found the weld must be made very quickly to “beat” heat conduction into the base material that would cause lack of fusion. Our LAB work had also shown it was very important not to allow the wire to shunt current to one side of the joint. A special device prevented shutting. These 3-foot high 12-inch-wide welds were made in about 20 minutes arc on time.

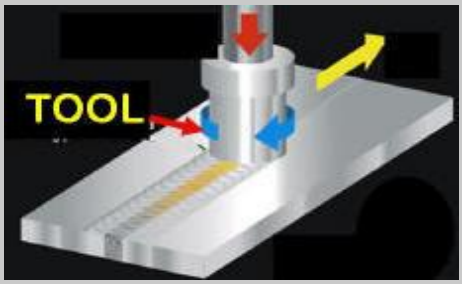
The molten flux height must also be controlled to avoid being too low or excessively high. It is controlled mostly by observation and sound.

Welding current for each guide tube was high requiring five 1000 amps power sources.

It takes operator skill, and the Canadian Company has made hundreds of welds both in their plant and at customer locations.

Friction Sir Welding (FSW)

In 1991 a novel welding method was conceived by TWI in the UK. US Patented number is 5,460,317 was filed in 1992. It does not melt the welded material, simply softens and with pressure applied, the joint is completed.



We supported the FSW sold to make rocket cases. It was made from ½ inch thick 7000 high strength aluminum. Prior to FSW arc welding as used. However, the joint strength was only half when arc welded.

In typical Aerospace procedure they welded a 1-inch-thick plate and then machined 90 percent away leaving only the weld joint are 1 inch thick!

With FSW, as the materials are NOT melted, they were able to weld the ½ inch thick material directly with minimal strength loss saving millions of dollars!

Recommended Reading

- **“Lincoln’s Incentive System” By James F. Lincoln, 1946**
- **“Incentive Management “ By James F. Lincoln, 1951**
- **“A New Approach to industrial Economics” By James F. Lincoln, 1961**
- **“The American Century of John C Lincoln” By Raymond Moley,1961**
- **“Lincoln Electric: A History” By Virgina Dawson, 1999**
- **“Behind the Mask” By Donald F. Hastings & Leslie Anne Hastings, 2014**

Other Internet References:

Original Paper, Updated and Expanded:
http://netwelding.com/Taylor_Ford_Lincoln_Business_Ideas.pdf

Another Showing How L-TEC Managed to Successfully Compete With Low Cost Producers:
http://netwelding.com/Competing_with_Low-Cost_Producers.pdf