WLD 131
Introduction to the
Gas Metal Arc Welding Process

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Opinions expressed are those of the authors And not necessarily those of the Foundation

PCC/ CCOG / WLD

Course Number:
WLD 131

Course Title:
Gas Metal Arc Welding

Credit Hours:
4

Lecture Hours:
0

Lecture/Lab Hours:
80

Lab Hours:
0

Special Fee:
$24.00

Course Description

Develops knowledge and skills welding with GMAW on ferrous materials using short circuit and axial spray transfers in common welding positions. Prerequisites: Department permission required. Audit available.

Addendum to Course Description

This is an outcome based course utilizing a lecture/lab format. This course includes classroom discussions, videos, and lab demonstrations of technical skills. Course outcomes will include: theoretical concepts, lay out, fabrication, welding, oxy-fuel cutting and safety.

Intended Outcomes for the course

Upon completion of the course students should be able to:

- Function safely in the PCC Welding Lab.
- Interpret blueprints to accurately lay out, prepare, and assemble weld joints.
- Understand and apply fundamentals of GMAW operations.
- Weld common joint assemblies with the GMAW to AWS D1.1 Structural Steel Welding Code visual acceptance criteria.
- Apply visual and destructive examination principles and practices in accordance with AWS D1.1.

Course Activities and Design

Welding lec/lab courses are Open Entry and Open Exit (OE/OE) and are offered concurrently. Courses are designed to meet the needs of the students with flexible scheduling options. Students may attend full time or part time. This is an OE/OE course which does not align with the normal academic calendar.

Outcome Assessment Strategies

The course syllabus will identify the methods used to assess student progress and the criteria for assigning a course grade. The student will be assessed on his/her ability to demonstrate the development of course outcomes. The methods of assessment may include one or more of the following: oral or written examinations, quizzes, written assignments and welding tests.

Course Content (Themes, Concepts, Issues and Skills)

Function safely in the PCC Welding Lab.

- Understand and practice personal safety by using proper protective gear
- Understand and practice power tool safety
- Understand and maintain a safe work area
  - Recognize and report dangerous electrical and air/gas hose connections
  - Understand and practice fire prevention

Interpret blueprints to accurately layout, prepare, and assemble weld joints.

- Interpret lines, symbols, views and notes
- Lay out material per specifications
- Assemble project per specifications

Understand and apply fundamentals of GMAW operations.

- Describe and demonstrate equipment setup, shut down, and operation
- Identify electrode types
- Demonstrate proper stick out and travel speed
- Demonstrate correct starting, stopping and restarting techniques
- Demonstrate proper bead placement

Weld common joint assemblies with the GMAW to AWS D1.1 Structural Steel Welding Code visual acceptance criteria in the following joints and positions:

Flat Position: (SCT, GMAW-S)

- Bead plate
- Butt joint
- T joint

Horizontal Position: (SCT, GMAW-S)

- T-Joint
- Lap Joint
- Butt Joint

Vertical Position: (SCT)

- T-Joint
- Lap Joint
- Butt Joint

Overhead Position: (SCT)

- T-Joint
- Lap Joint
- Butt Joint

Apply visual and destructive examination principles and practices in accordance with AWS D1.1.

Evaluate welds using appropriate welding inspection tools

Assess weld discontinuities causes and corrections

GAS METAL ARC PROCESS AND WELDING VARIABLES

There have been many names attached to the gas metal arc process since its inception in 1948. The generic terms most often used are "MIG" (an acronym for Metal Inert Gas) or "short-arc." Which is “short” for Short Circuit Transfer. The names used are usually descriptive of the process technique.

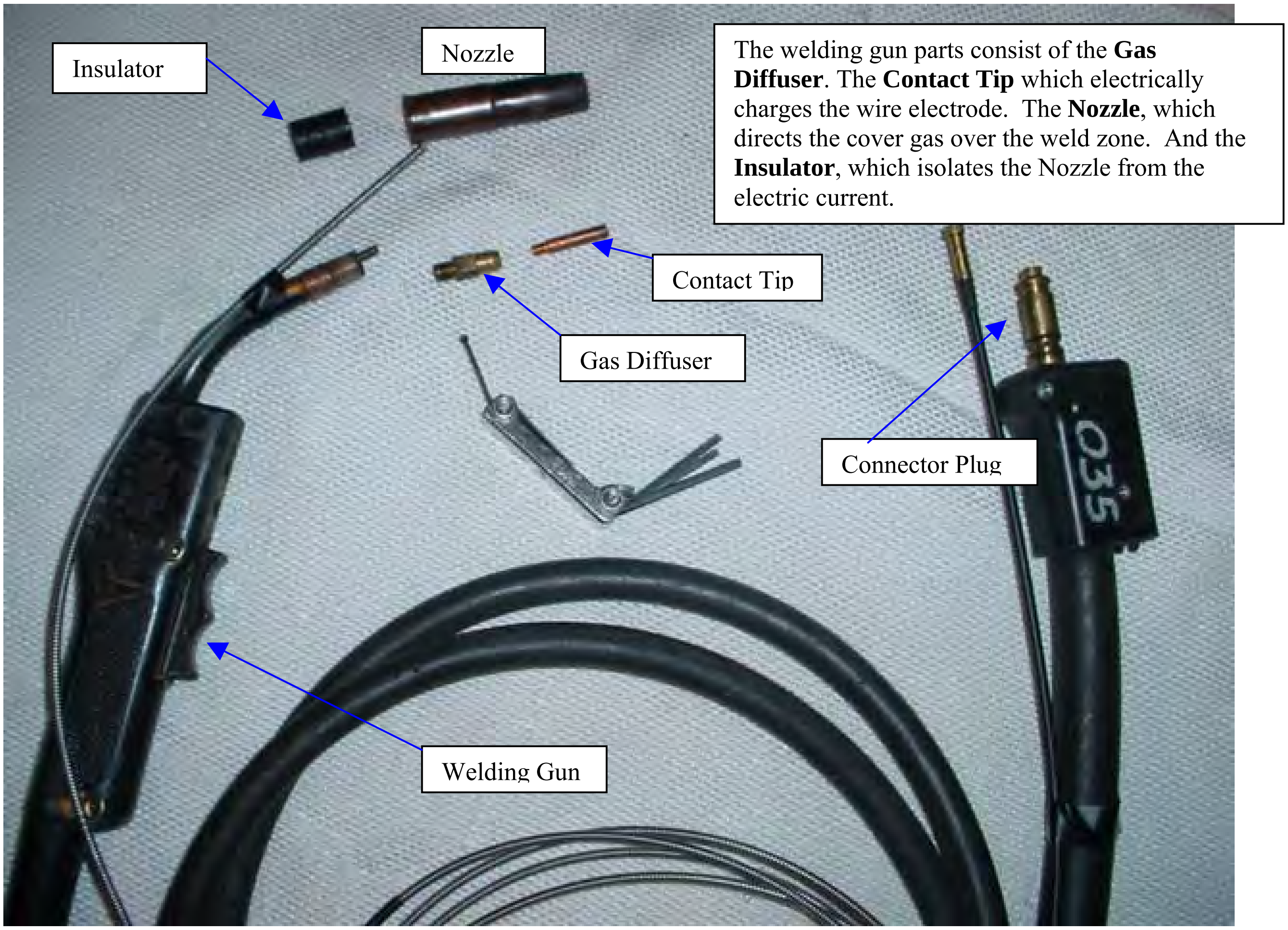
The gas metal arc process was first developed for the purpose of welding heavy aluminum plates. The first wire drive units were crude, as compared to the units now on the market. The important thing is that they did the job and, more importantly, opened up an entirely new concept in welding.

Gas metal arc welding is an electric welding process in which a solid, bare electrode is continuously fed into the weld zone at a controlled, constant rate. The arc area is enveloped in a gas atmosphere. This process is based on the use of relatively high amperages with relatively small diameter electrode wires, or high current density. High current density may be explained as amperage per square inch of cross sectional area.

The fundamental equipment necessary to function with the gas metal arc process includes a welding machine, a wire feeder, a control, a gun, and the interconnecting cables, hoses, etc. The correct shielding gas and electrode wire complete the assembly. If the gun is water cooled, a source of water must be provided.

POWER SOURCES

The gas metal arc process operates on direct current, reverse polarity. At the time of the original development of the process there was a limited selection of DC welding machines available. With the increased demand on the process to do more and different applications came the need for welding machines that could extend the versatility of the wire drive equipment to perform satisfactorily on such applications. Because of these demands the constant-potential (also called “CV” or Constant Voltage) type welding machine was developed.



For more information on the welding gun and it's parts see INDEX of "**Welding Principles and Applications**"

4. IMPORTANT When the conduit is fully inserted into the cable/hose and the conduit stop is firmly against the Connector Plug, the raw end of the conduit will protrude out of the open end of the gun conductor tube. Cut the conduit end off squarely outside the conductor tube according to dimensions in. The end cut which seats in the gas diffuser must be filled and reamed perfectly smooth on the inside and outside radii so that the wire feed will not be obstructed.

5. Seat the smoothed end of the wire conduit into the end of the Gas Diffuser and screw the diffuser into the conductor tube. When the Gas Diffuser is fully tightened, remove the small Allen screw to make sure that the conduit is visible throughout the screw hole. This inspection will assure that the wire conduit is fully seated in the Gas Diffuser. Replace and securely tighten the Allen screw into the conduit. DO NOT OVERTIGHTEN CAUSING DISTORTION OF THE CONDUIT.

Welding Vocabulary

Minus arc Length — Result of low voltage and/or high electrode feed speed (current) which gives a shorter arc length. The tip of the electrode is below the surface of the base metal.

Plus arc length — Result of high voltage and/or slow electrode feed speed (current) which gives a longer arc. The tip of the electrode and a portion of the arc stream is clearly visible above the surface of the base metal.

Zero arc length — Balanced arc is a condition obtained when the electrical feed speed is adjusted so that the current bring supplied by the power source melts the electrode at a rate that maintains the top of the electrode very nearly level with the surface to the base metal.

Automatic Welding — Welding with equipment which performs the entire welding operation without constant observation and adjustment of the controls by an operator. The equipment may or may not perform the loading and unloading of the work.

Coalescence — The flowing together or growth into one body of the base metal and filler material parts.

Contactor — A device for repeatedly establishing and interrupting the electric power circuit.

Contact tip — A device which transfers current to a continuous electrode.

Electrode (wire) — The length of electrode (wire) extended from the contact tip to the work surface.

Stick out — Recommended ¼” maximum stickout for Short Circuit Transfer (SCT) and Surface Tension Transfer (STT).

Nozzle-to-Work Distance — The distance measured from the end of the nozzle to the work Surface.

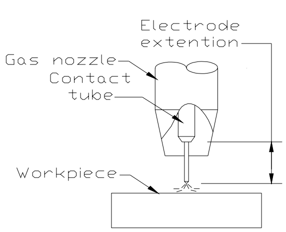


Figure 7-2. Electrode extenion. The actual electrode extenion is from the end of the ontact tip to the of the electrode. The proper term is "eltrical stickout" and is defined on weld procedure with the letters ESO.

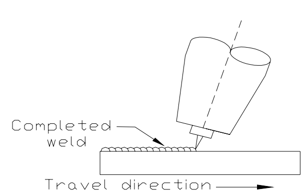


Figure 7-4. Backhand or pull welding technique. This technique requires more skill on the part of welder, since the weld joint is defficult to see because of the position of the gas nozzle.

Fillet Throat Dimensions Size of the weld measured at the Throat of the Weld.

Flow meter A metering device developed to control the flow of shielding gases. The flow of shielding gases is indicated on a flowmeter. tube which is calibrated for the gas being used in cubic feet per hour (cfh).

Fusion The melting together of filler metal and base metal, or of base metal only, which results in coalescence.

Gas Diffuser A device located in the gun that disperses the shielding gas into the nozzle, it also holds one end of the wire conduit firm and is a receptacle for the contact tip.

Gas Metal ARC Welding An arc welding process wherein coalescence is produced by heating with an arc between a continuous filler metal (consumable) electrode and the work. Shielding is obtained entirely from an externally supplied gas, or gas mixture, some methods of the process are called MIG or C02 welding.

Gun (Welding) In semiautomatic, machine and automatic welding, the gun "acts" as a manipulating device to transfer current and guide the electrode into the arc. It may include provisions for shielding and arc initiation.

Current conductor tube (GMAW)- A hose like device-through which the electrode, current, shielding gas (if any), and coolant (when used) travels from the power source of wire feeder to the gun

Nozzle A device which directs the shielding gas.

Regulator A device for controlling the delivery of gas at some constant pressure regardless of variation in the higher pressure at the source.

Semiautomatic Arc Welding Arc welding with equipment which controls only the filler metal feed, the advance of the welding is manually controlled.

Spatter In arc and gas welding, the metal particles expelled during welding which do not form a part of the weld.

Travel Angle Is the relative angle of the welding gun and the direction of travel.

Travel Rate Is the relative speed of progression along the work surface.

Voltage The measurement of electrical pressure. Voltage controls the maximum gap the electrons can jump from the arc.

Arc Voltage	The voltage across the welding arc.
Open Circuit Voltage	The voltage output of the welding machine when no current is in the welding circuit.
Weldment	An assembly whose component parts are joined by Welding.
Weld Reinforcement	The weld on the face of the weld in excess of the original surface of the base metal.
Weld Penetration	Measured from the original surface of the base metal. The depth of fusion or melting.
Fusion Line	The junction of the weld metal with the unmelted base material.
Heat Affected Zone	That portion of the base metal immediately adjacent to the fusion line which has not been melted, but in which the mechanical properties and microstructure have been altered by the heat of welding.
Welder	One who is capable of performing a manual or semiautomatic welding operation. Sometimes erroneously used to denote a welding machine.
Wire Conduit	A round tube located in the gun conductor tube through which the electrode travels from the wire feeder to the gun. This conduit may or may not be removable depending upon the manufacturer of the equipment.
Welding current	Welding current (measured in amperes). The movement of electrons in a completed weld circuit.

Wire Feeder

An assembly that provides the driving or pulling power to transport the electrodes through the gun conductor tube and the gun to the work. There are three types of systems:

1. **PUSH:** Drive rolls push the wire through the conductor type.

2. **PULL:** Drive rolls are located in the gun and pulls the electrode through the conductor tube.

3. **PUSH-PULL:** A system of drive rolls are located at both ends of the conductor tube. One set in the gun that pulls and one set at the base of the conductor tube that pushes. Used mostly for soft or small diameter wires.

Work Angle

The angle that the electrode makes with a line perpendicular to the weld axis at the point of welding taken in a transverse plane.

Science On Steel

Contents of this Packet are

- Gas Shielding used with GMAW
- Use of Diatomic Gases with Argon or Helium
- Stabilizing the arc for GMAW of Steel
- Axial Spray GMAW
- "Fingerlike" Penetration with Pure Ar Spray GMAW
- When to Use Ar-He vs. Ar-CO_2 vs. Ar-O_2 Spray Arc GMAW
- Oxidation Potential of Ar-Rich Gas Mixtures
- Optimum Gas Flow Rate
- Comparing GMAW of Steel vs. Aluminum
- Porosity in Aluminum Weld Metal
- Globular Transfer GMAW
- Short Circuiting Transfer for Out-of-Position GMAW
- Surface Tension Transfer (STT) GMAW

Gas Shielding used with GMAW

Although gas metal arc welding of steel is performed routinely, it is a very complicated process involving gas-metal reactions affecting the resulting mode of metal transfer and weld quality. The gases commonly used for GMAW include:

- argon (Ar) - Inert
- helium (He) - Inert
- carbon dioxide (CO_2)- Chemically Active
- hydrogen (H) - Chemically Active
- nitrogen (N) - Chemically Active

As shown above, Ar and He are totally inert because their outer shell of electrons is "full". Chemical reactions between gases and weld metal can only take place if the gas is active like H, N, and CO_2 because these gases have partially filled outer shells containing "valence electrons" that can bond with other materials. For example, oxygen has an unfilled outer electron shell containing valence electrons, which combine with the valence electrons of the molten iron to form iron oxide. Such a reaction cannot happen with Ar or He. Thus, Ar and He provide excellent protection of the molten weld pool because no chemical reaction can occur between Ar, He and molten metal. Although pure nitrogen is reactive when used with aluminum or steel, it is relatively inert when welding copper. The shield gas composition greatly affects the burn-off rate, type of metal transfer (short circuit, globular, or spray), and penetration.

Use of Diatomic Gases with Argon or Helium

When a diatomic gas like H_2 , O_2 , or N_2 is used with Ar or He, the effect is to produce a hotter arc similar to an increase in the welding voltage. Diatomic gas will increase the heat transferred to the molten pool. For example, when H_2 dissociates into 2H atoms in the arc, heat is extracted from the very hot arc for this dissociation to take place. When the 2H atoms reach the cooler molten pool, H_2 forms (exothermically) and a great amount of heat is pumped into the weld. This exothermic reaction is helpful when welding thick plates of highly conductive metals like copper. Here again, the use of pure N_2 or Ar + N_2 provide an intensely hot arc for welding copper.

Stabilizing the Arc for GMAW of Steel
Although Oxygen (O) forms oxide inclusions in the weld metal, O must be added to Ar in order to stabilize the arc when welding steel. CO_2 can also be added to Ar for arc stability because during welding CO_2 breaks down to carbon monoxide (CO) plus oxygen as shown below:

$$CO_2 \rightarrow CO + O_2 .$$

If oxygen comes into contact with the molten metal, a metal oxide will form instantly. For example, Ar-2%O is commonly used to weld steel. The 2% O combines with iron to form iron oxide in the molten weld pool as well as on the hot wire entering the weld zone. When GMAW steel, DCep is used, so the weld pool is the cathode and the filler wire is the anode. In order for an arc to be stable, it must be rooted to cathode spot on the weld pool closest to the electrode. Similarly, the anode spot must be stable and located at the end of the electrode. If the anode and cathode spots are not stable, the arc will wander all over the weld pool as well as up and down the wire electrode. The presence of 1-5% oxygen in Ar shielding provides enough oxide layer to stabilize the arc by stabilizing the cathode and anode spots. The oxide substantially reduces the "work function" of the cathode, that is the energy required to emit an electron from the cathode and pass through the arc to the stable anode spot. The oxide has this property of stabilizing the anode and cathode spots. As a result, welding gases used for GMAW steel can never be composed of pure Ar, otherwise arc instability will occur. The welding gases must be Ar-1% to 5%O, or various mixtures of Ar and at least 5%CO_2 . Even pure CO_2 can be used. However, the greater the Ar content the less spatter and greater the mechanical properties of the weld metal.

Axial Spray GMAW
For reasons that are not well understood, argon is the only shielding gas that is capable of producing an axially-propelled spray arc that is quiet, stable, spatter-free, and highly directed. Spray arc produces over 100 droplets/s, and these droplets are smaller than the filler metal diameter. The greater the welding current, the finer and more numerous will be the metal droplets in spray GMAW. For any diameter of filler metal, there is a threshold value of current, above which a directed axial spray mode of metal transfer occurs. The transition current to spray is proportional to the wire diameter. Despite the fact that helium and CO_2 have much higher ionization potentials than Ar, neither helium nor CO_2 are capable of producing a spray transfer. Although helium and CO_2 can generate a greater heat input than Ar, the mode of droplet transfer is a non-directed globular transfer through the arc.

Fortunately, however, we can take advantage of the high-heat-input characteristics of helium, CO_2, and other gases by mixing these gases with Ar. As long as there is more than a critical amount of Ar present in the gas mixture, a true spray arc can be achieved while the heat-producing effects of helium, CO_2 , O, N, and H are obtained. For example, true spray can be obtained with the following Ar gas mixtures :

Ar-He mixtures containing at least 80%Ar
- Ar-CO_2 mixtures containing at least 85%Ar
- Ar-O_2 mixtures containing at least 95%Ar

The size of droplets in spray transfer are characteristically smaller than the diameter of the wire. As current increases, drop size decreases but frequency of droplets and deposition rate increase. With increasing current, wire diameter must increase to maintain a smooth and stable arc. Because the heat input for spray arc is high, only flat and horizontal fillets positions are used. Using DCEP with a spray arc, the maximum penetration is obtained for GMAW.

"Fingerlike" Penetration with Pure Argon Spray GMAW

The directed axial flow of over 100 droplets/s produces a visible depression of the molten weld pool under the spray arc. The momentum of the rapid stream of axially directed droplets provides the mechanism for deep penetration directly beneath the arc with very little penetration along the sidewalls of the weld pool. The kinematic viscosity (defined as the viscosity multiplied by the density) of the shielding gas has a substantial effect of penetration. Since Ar has a greater kinematic viscosity than He, the axially directed penetration of Ar is far greater than that for He even though He has a higher ionization potential than Ar. This is why Ar produces fingerlike penetration and He produces more uniform penetration. Since penetration is affected by viscosity and density of the shielding gas, increasing the ambient pressure during welding can also decrease penetration. Increasing pressure of Ar atoms produces a drag or friction force resisting the speed of droplets streaming into the weld pool. As a result, increasing ambient pressure decreases weld penetration.

Fingerlike penetration of Ar spray GMAW is not desirable in welds. The most effective way to eliminate fingerlike penetration and promote a more uniform penetration pattern is by the addition of small amounts of a second gas. For example, Ar with 2 to 5% O or Ar with 5 to 25% CO_2 greatly reduces and even eliminates fingerlike penetration. As discussed earlier, the primary purpose of adding O_2 or CO_2 to Ar is to establish arc stability. However, a secondary benefit of adding O_2 or CO_2 to Ar is to eliminate fingerlike penetration.

When to Use Ar-He vs. Ar-CO_2 vs. Ar-O_2 Spray Arc GMAW

The only gases that can be used to weld reactive metals (like aluminum, magnesium, and others) are either pure Ar or Ar-He mixtures. Since both Ar and He are inert, the reactive metals will not be contaminated during welding. Also, aluminum and magnesium have such thick refractory oxide layers that neither Ar-CO_2 nor Ar-O_2 mixtures are needed to achieve arc stability when welding these metals. In fact, the presence of CO_2 or O_2 would substantially oxidize and deteriorate the weld metal by impairing its mechanical properties. Thus, only pure Ar or Ar-He mixtures can be used to weld aluminum and magnesium. For thin sections, pure Ar is adequate. When high heat input welds are deposited on thick-section aluminum or aluminum alloys, a mixture of Ar and He is needed.

The GMAW process readily welds steel, but pure Ar can not be used due to the arc instability problem (discussed above). For high toughness applications, steels used in shipbuilding and bridges are usually welded with Ar-2%O or Ar-5%CO_2. In this way, only the minimum amount of O or CO_2 is used for arc stability. If more than 2%O or 5%CO_2 are used, excessive oxidation and carburization would severely impair mechanical properties particularly Charpy impact toughness. To ensure good Charpy impact toughness, steel filler metals contain Si, Mn, and/or Al deoxidizers. Oxides of Si, Mn, and Al (such as SiO_2, MnO, and Al_2O_3) are formed in the weld metal. Since the densities of these oxides are much lower than the molten steel weld metal, most of the oxides float to the top of the pool forming very thin islands of glassy slag.

Oxidation Potential of Argon-Rich Gas Mixtures

The addition of CO_2 or O_2 to argon to increase arc stability, which is required for GMAW of steel, also oxidizes the molten steel but to different degrees. The oxidation potential of Ar containing 1 to 3% O_2 is equivalent to about Ar containing 2 to 4% CO_2 . The oxidation potential of Ar containing up to 30% CO_2 is roughly similar to Ar-O_2 mixtures containing O_2 about half the level of CO_2.

Optimum Gas Flow Rate

It is sometimes believed that increasing Ar gas flow rate to higher and higher levels provides increased protection for the weld pool. This is only true up to a certain critical value of flow rate, and then detrimental turbulence occurs. Once turbulence occurs, the air contamination is entrained into the gas column across the arc. The formation of turbulence is dependent upon the Reynolds Number (R) for the flowing gas. R is calculated from:

$$R = Dv\rho / \mu$$

Where, D is the diameter of the tube or nozzle diameter, v is the average gas velocity, ρ is the density of the gas, and μ is the viscosity of the gas.
If the Reynolds Number exceeds 2300, the flow becomes turbulent. Unfortunately, the larger the diameter nozzle, the lower the critical gas flow velocity is for turbulent flow. So, there is only a limited improvement in Ar gas shielding by using larger diameter nozzles. Since gun design also affects Reynolds Number, the manufacturer's recommendations for gas flow settings are important for best protection of the weld pool.

Comparing GMAW of Steel vs. Aluminum

Because aluminum has much higher thermal and electrical conductivity, greater thermal diffusivity, greater chemical reactivity, less solid solubility of hydrogen than steel, GMAW of aluminum is much more difficult-to-control than welding steel. When similar welds are deposited on aluminum and steel, the aluminum weld metal is more susceptible to porosity, more sensitive to changes in welding parameters and more susceptible to burn-through defects in root passes. For example, in comparing similar welds of aluminum and steel, the aluminum weld is over 10 times more sensitive to changes in wire feed rate than is steel. Unlike steel, small changes in wire feed rate causes a substantial change in arc length. In addition, because aluminum is so much more electrically conductive than steel, the use of "stick out" to control arc characteristics such as deposition rate are not as effective as that for steel.

Porosity in Aluminum Weld Metal

During GMAW, both steel and aluminum weld metal absorb ionized hydrogen from the arc atmosphere when water vapor, oil, grease, paint and other hydrocarbon impurities are present during welding. For example, aluminum can absorb substantial quantities of hydrogen. From the equation below, the solubility of hydrogen in aluminum (S) increases with increasing hydrogen contamination in the arc atmosphere and the temperature of the molten aluminum.

$$S = 625.2\, p^{1/2}\, e^{-6355/T}$$

Where p is the partial pressure of hydrogen contamination with argon in arc and T is the temperature of the molten aluminum.

Both aluminum and steel readily dissolves hydrogen during welding. When the weld pool solidifies, the steel still contains substantial dissolved hydrogen in a supersaturated solid solution. So, steel weld metal is not very susceptible to porosity unless the hydrogen level is extremely high. However, aluminum does not tolerate any hydrogen during solidification and rejects all of it during solidification. As a result, the sudden rejection of hydrogen gas from the solid aluminum to the remaining liquid causes massive amounts of hydrogen porosity. This is the reason why aluminum welds are extremely sensitive to porosity. All aluminum consumables and work pieces must be extremely clean to prevent porosity in welds. Workmanship standards for welding aluminum must include much higher degree of cleanliness in both the wire and work piece than for similar welding of steel. Any source of hydrogen (moisture, oil, grease, paint, etc) is immediately converted to porosity. Steel welds are much less sensitive to porosity.

Globular transfer GMAW

The normal mode of metal transfer using virtually any gas shielding such as He and CO_2 is by a non-directed and erratic globular transfer, which produces about 1 to 10 drops/s. Even Ar produces globular transfer below a certain critical amperage for a particular diameter of filler metal. The problem with globular transfer is that it produces spatter and is naturally difficult for out-of-position welding because metal transfer is controlled mostly by gravity (and there is not fast freezing flux to support the weld pool as in FCAW). A droplet grows to a size larger than the diameter of the electrode and eventually falls off due to gravitational forces. Although He and CO_2 always produce non-directed globular transfer with spatter, they are still used because they provide much higher welding heat input than argon for thick section welding, particularly welding of aluminum.

Short Circuiting Transfer for Out-of-Position GMAW

Short Circuit arc transfer “Short Arc” GMAW is used for out-of-position welding and for thin materials. Short arc provides a “cold” weld pool with lowest current density and produces small welds with little distortion. Short arc is obtained by using lower voltages than is used with globular transfer and low currents, so that the feed rate of small diameter wire exceeds burn-off rate. Short circuiting or dipping occurs from 20 to 200/s. For example, the transition current for short circuit welding of steel is proportional to the wire diameter as shown below:

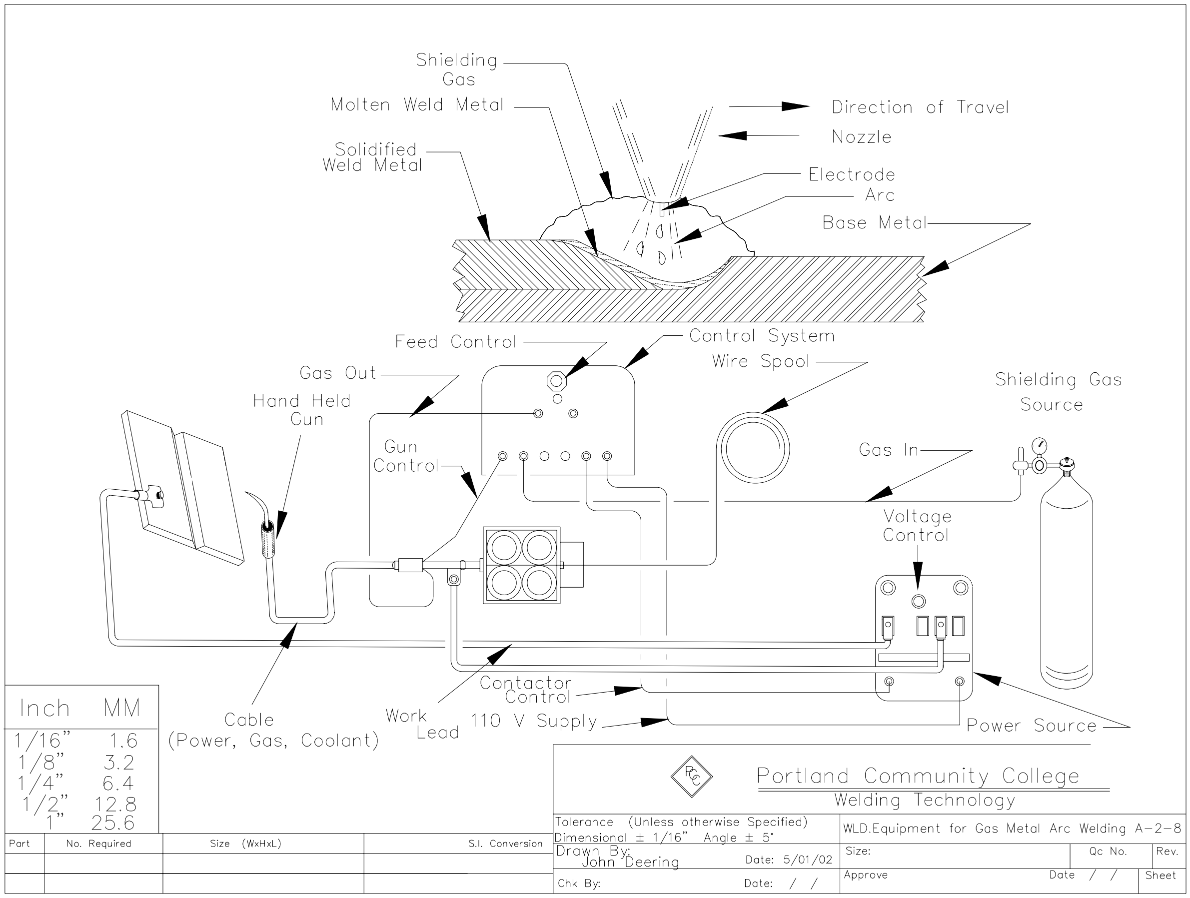
Wire Diameter	Welding Current
0.030 in	50-150 A
0.035 in	75-175 A
0.045 in	100-225 A

The reason why out-of-position welding is possible is because the weld pool is so small and “cold” that the surface tension forces, which hold the molten pool in place, exceed the gravitational forces. Until recently, only short arc was capable of welding out-of-position welding because both globular or spray transfer were best utilized for flat position welding. With the development of pulsed power supplies, out-of-position GMAW can be use with either globular or spray (preferred) modes of transfer.

Surface Tension Transfer (STT) GMAW

Through electronic circuitry, the STT GMAW process is a highly controlled adaptation of the short circuit GMAW process. The STT process utilizes modern electronic power circuits to control the metal transfer during short circuit arc transfer welding. STT GMAW is a modification to short circuit GMAW where the output waveform is controlled by the machine's electrical circuitry. Metals commonly welded by STT are steel, stainless steel, nickel alloys, titanium and even copper alloys. STT process accurately controls heat input and penetration independently of wire feed speed. In this way, the major benefits of short circuit arc welding (such as out-of-position and low heat input) are retained, while the problems with short circuit arc welding (such as weld spatter) are greatly reduced.

Spatter is inherent in conventional short circuit GMAW because of the very high "pinch" current effect during the high current portion of the short-circuiting cycle, immediately after re-ignition of the arc. In STT, the electronic circuitry cuts the current nearly to zero at the precise instant of time when the "pinch" effect and spatter generation is maximum. Thus, the small portion of the short-circuiting GMAW cycle that produces the greatest amount of spatter is significantly reduced. Because of this control, the STT process can be used for out-of-position welding as well as for root passes in pipe.



SCHEMATIC OF GMAW EQUIPMENT

CONSTANT POTENTIAL (CONSTANT VOLTAGE) POWER SOURCE

This type power supply has a flat volt-ampere characteristic. It has a wider range of arc self-correction than the constant current type. Electronic governing types of wire feeding apparatus are also used with this type of power supply.

With this system, arc voltage or load voltage selection is made on the power supply. The wire feed speed controls the arc current. The wire, again, is fed at a controlled speed. with a slow wire speed. The current output of the power supply is low. If a high wire speed is used, the welding current is high. Although a uniform distance from the torch nozzle to the work is recommended with this system. The operator has more leeway when the constant potential type power source is used with the short-circuiting transfer (short arc) also called SCT for Short Circuit Transfer. Surface Tension Transfer or STT is another form of "Clean" Short Arc.

Modified constant potential power supplies are designed to provide complete control load voltage, variable, tapped or preset slope, and preset to tapped control of the stabilizer (incubator). The slope and the inductance may be built in at optimum values, and they adjust automatically with the output. With the slope, voltage, and stabilizer as variables, it is possible to select the best possible arc characteristics available.

INDUCTANCE (Pinch Effect)

Inductance is a resistance to current flow. It generally is physically located in the DC side of a power supply circuit. This is usually accomplished by the use of turns of copper wire around an iron core. It may be built into the power source or added externally.

The function of an inductor is to retard the rate of change of current in a DC circuit. It acts in a manner to slow up the rate of rise of current. Inductance is important in the short circuit transfer process because it allows more efficient use of the arc voltage during the arc "on" time of the short circuit cycle.

To use figures for an example:
Suppose during a short circuit cycle the arc is "on" 50% of the time and 50% of the time it is "off." By adding a stabilizer (inductance), the relationship of the arc "on" time to the arc "off" time may be changed. The addition of inductance not only changes the arc "on" and "off" relationship, but also reduces the short circuit frequency. Both of these things amount to more arc "on" time. More arc "on" time means to the puddle that (1) fluidity will be increased, (2) penetration is a little deeper, (3) bead shape is flatter and smoother, and (4) freeze lines are tighter knit. Another big feature of inductance is that it reduces spatter.

Inductance makes the arc softer by tailing away the digging action. Bad effects of inductance are the arc is more susceptible to magnetic effects (arc blow), plus much too much inductance, coupled with wire feed problems, can cause burn back.

SLOPE

The word “SLOPE” in GMAW refers to the slant of the volt-amphere curve and the operating characteristics of the power supply under load. In many machines the slant of the volt-amphere curve is automatically set as you change the open circuit voltage. In others the slope can be changed by the operator for different modes of Welding. The curve is known as either flat or steep mode.

The slope controls the amount of current available from the power supply on SHORT CIRCUIT. This current acts in a manner to exert a "pinch force" on the wire, which causes the wire to "neck down" and finally separate from the work piece.

Generally, slope is put in a power supply by changing the resistance and /or impedance in the AC side of the secondary. This may be accomplished by winding the primary and secondary coils tight (no resistance of impedance).

Slope may also be introduced by putting a coil, (impedance) or a resistance downstream of a tightly wrapped coil. A particular slope is put in a power supply to satisfy the particular requirements of a given process for welding.

There are basically four kinds of slope:

1: Drooping volt-ampere curve
2: Flat volt-ampere curve
3: Modified flat volt-ampere curve
4: Rising volt-ampere curve

FLAT VOLT AMPERE CURVE

The flat volt-ampere curve (Figure 10) is a constant voltage curve. It is called constant potential or constant voltage.

On this constant potential curve, the welding current would be 150 amperes al 24 volts. As the current varies, there is little change in arc voltage along the entire line.

Two main features of this type power supply are low open circuit voltage and high short circuit currents. This machine is used with wire feeding apparatus in the GMAW, FCAW, and other wire processes.

VOLTAGE

Voltage wets the base metal. High voltage will give a long arc length and produce a wider weld. Low Voltage will give a tight arc length and the weld bead is narrow. Voltage is also one of the factors that determines the mode of metal transfer, discussed later. No specific values of arc voltage are consistently appropriate for normal production welding. Trial runs are necessary to adjust the arc voltage if it is to produce the most favorable filler metal transfer and weld bead appearance. These trial runs are essential because arc voltage is dependent upon a variety of factors, including metal thickness, the type of joint, the position of welding, electrode size, shielding gas composition, and the type of weld. From any specific value of arc voltage, a voltage increase tends to flatten the weld bead and increase the fusion zone width. Reduction in voltage results in a narrower weld bead with a high crown. Excessively high voltage may cause porosity, spatter and undercutting; excessively low voltage may cause porosity and overlap at the weld edges.

TRAVEL SPEED

Travel speed is the linear rate at which the arc is moved along the weld joint. With all other conditions held constant weld penetration is a maximum at some travel speed. The penetration will decrease when the travel speed is increased, and the weld bead will become narrower.

When the travel speed is decreased, the filler metal deposition per unit length increases, and a large, shallow weld pool is produced. The welding arc impinges on this pool rather than the base metal as the arc advances. This limits penetration but produces a wide weld bead.

As the travel speed is increased, the thermal energy transmitted to the base metal from the arc is increased melting of the base metal is slowed and occurs nearer to the surface of the base metal. As travel speed is increased further, there is a tendency toward undercutting along the edges of the weld bead because there is insufficient deposition of filler metal to fill the path melted by the arc.

ELECTRODE EXTENSION (Also known as *Stick Out*)

The electrode extension is the distance between the last point of electrical contact, usually the end of the contact tube, and the end of the electrode. Resistance heating causes the electrode temperature to rise.

There is a need to control electrode extension, because too long an extension results in excess weld metal being deposited with low arc heat. This will cause poor weld bead shape and shallow penetration also, as the contact tube-to-work distance increases, the arc becomes less stable. Good electrode extension is from 1/4" to 3/8" for short circuiting transfer (SCT) and Surface Tension Transfer (STT).

ELECTRODE POSITION (*Travel Angle and Work Angle*)

As with all arc welding processes, the position of the welding electrode with respect to the weld joint affects the weld bead shape and penetration. The effects are greater than those of arc travel angle. Electrode position is described by the relationships of the electrode axis with respect to (1) the direction of travel, (2) the travel angle, and (3) the angle between the axis and the adjacent work surface (work angle). When the electrode points opposite from the direction of travel. It is called the backhand welding technique. When the electrode points in the direction of travel, is called the forehand welding technique.

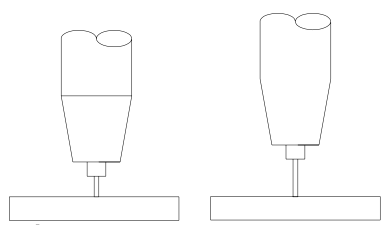


Figure 7-3. Electrode extion variations. Use these variation from the welding procedure dimenions to increase or decrease welding heat into the weld poole.

When the electrode is changed from the perpendicular to the forehand technique with all other conditions unchanged, the penetration decreases and the weld bead becomes wider and flatter. Maximum penetration is obtained in the flat position with the backhand technique at a travel angle of about 25 degrees from the perpendicular, backhand technique also produces a more convex, narrower bead, a more stable arc, and less spatter on the workplace.

When producing fillet welds in the horizontal position, the electrode should be positioned about 45 degrees to the vertical member (work angle). For all positions, the electrode travel angle normally used is in the range of 5 to 15 degrees for good control of the molten weld pool.

SHIELDING GASES

When molten, most metals combine with the basic elements in air, oxygen, and nitrogen to form metal oxides and nitrides contamination of the weld metal can result in low strength, low ductility and excessive weld defects such as porosity and lack of fusion.

The primary purpose of the shielding gas in GMAW is to protect the molten weld metal from contamination and damage by the surrounding atmosphere. However, several other factors affect the choice of a shielding gas some of these factors are as follows:

1. Arc and metal transfer characteristics during welding
2. penetration, width of fusion, and shape of reinforcement
3. Speed-of welding
4. Undercutting tendency

All of the above factors influence the finished weld and the overall result. Cost must also be considered.

Argon and helium, used most frequently for GMAW of nonferrous metals, are completely inert. The selection of one or the other, or mixtures of the two in various combinations, can be made so that the desirable metal transfer, penetration bead geometry, and other weld characteristics can be obtained.

Although the pure inert gases protect the weld metal from reaction with air, they are not suitable for all welding applications. By mixing controlled quantities of reactive gases with them, a stable arc and substantially spatter-free metal transfer are obtained simultaneously. Reactive gases and mixtures of such gases provide other types of arcs and metal transfer. Only a few reactive gases have been successfully used either alone or in combination with inert gases for welding. These reactive gases include oxygen, nitrogen and carbon dioxide. Although hydrogen and nitrogen have been considered as additives to control the amount of the joint penetration they are recommended only for a limited number of highly specialized applications where their presence will not cause porosity or embrittlement of the weld metal. As a rule, it is not practical to use the reactive gases alone for arc shielding Carbon dioxide is the outstanding exception. It is suitable alone or mixed with inert gas, or mixed with oxygen for welding a variety of carbon and low alloy steels. Carbon dioxide shielding is inexpensive. All the other gases except nitrogen are used chiefly as small additions to one of the inert gases (usually argon).

Nitrogen has been used alone, or mixed with argon, for welding copper. The most extensive use of nitrogen however, is in Europe where little or no helium is available.

SHIELDING A GAS SELECTION

The choice of a shielding gas depends on the metal to be welded, section thickness process variation, quality requirements metallurgical factors, and cost. Argon, helium and argon-helium mixtures are generally used with nonferrous metals. Argon-oxygen, argon-carbon dioxide, argon-helium mixtures, and also pure carbon dioxide are employed for ferrous metals. The application needs, therefore, determine shielding gas selection.

ARGON/CO-2 75-25 75-25 is the percentages of the mixed gases. In this case it would mean 75% Argon and 25% Carbon Dioxide.

***For More welding glossary terms see the “Welding Principles & Applications” book, page 835.**

MODE OF METAL TRANSFER

Transition Point

Every type and every diameter of wire has what is called a transition point. This point is different for each and every wire and it is different for each and every shielding gas.

The transition point is important to intelligently talk of different types of arc transfers. This is because it stands as a reference point or dividing line of the different types of arc transfers.

Short Circuiting Type Arc

A balanced, low current density arc where both requirements of current and voltage are below the transition point of the wire.

SHORT CIRCUITING TRANSFER

The short circuiting metal transfer is a rapidly short circuiting type of arc where the metal is pinched off the end of the electrode. The concept of this type of welding depends on actually making short circuit contact with the parent metal (see drawing). The heating of the wire causes it to "neck down" and burn off or pinch off, causing an arc to be established. The glob of metal deposited spreads out under the arc force, as the wire again advances to make contact with the base metal.

The short circuiting process is generally used on sheet material and out of position where low metal deposition is desired for puddle control. It is a medium speed welding process characterized by narrow beads with shallow penetration coming from a small, fast freezing weld puddle. This process is practiced generally with small diameter wire. Not exceeding wire size .045.

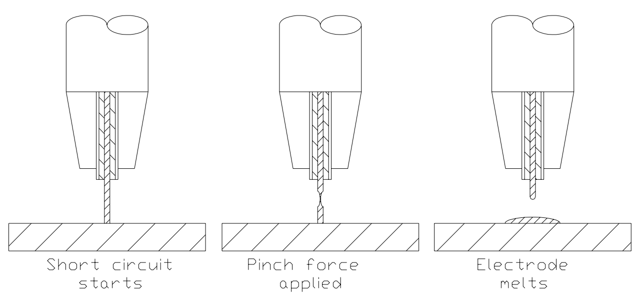


Figure 2-1 In the short-circuting-arc mode of metal deposition, the electrode actually touches the workpiece and melts about 20 to 200 times per second.

SURFACE TENSION TRANSFER

Surface Tension Transfer (STT) is a very special Lincoln Electric developed power source for short arc Welding. A result of inverter technology, this unit allows reduced spatter and fume with improved bead shape by precise control of the pulsed wave. STT operates neither in the constant current (CC) nor constant voltage (CV) mode. Rather it is a high-frequency (wide bandwidth), current controlled machine wherein the power to the arc is based on the instantaneous arc requirements, not on an "average DC voltage".

Surface Tension
A phenomenon which causes liquids in contact with their own vapors to reduce to a minimum area, as if covered by an invisible membrane. This effect is attributed to forces that arise across the surface of the liquid because the atoms or molecules at the exposed surface are subject to interatomic forces from within the liquid.

WELDING STEEL

Applications include all types of sheet metal fabrication, angle iron frames, starters for electric motors, root pass for pipe welding, maintenance work, and many others.

Since rework is always expensive (some times it can cost more than the original weld) it is to be avoided whenever possible. Some of the items that cause rework are inclusions, porosity lack of penetration, and lack of fusion. Of these the most common fault is porosity when using the GMAW process.

Porosity is one of the recurring problems faced in welding any metal. There are several general rules that will help to minimize porosity problems. The following data is not intended to answer all the reasons that porosity occurs, it will certainly help to decrease the possibility of porosity if due notice is made of the suggestions. *See "Welding Principles and Applications" 493-494 for more information on porosity.

1. Welding speeds that are too fast will cause either partial or complete loss of the shielding gas pattern in the arc area and will cause porosity.

2. Current densities that are too high will often cause porosity due to the excessive heat of the molten metal from the electrode. In some cases alloying and deoxidizing elements have excessive burnout across this type of arc.

3. Shielding gases used with the gas metal arc process must be of the right type for the metal being welded and must have the right flow in cubic feet per hour or unsatisfactory results will occur. Shielding gas flows are usually above 15 CHF but not more than 80 CFH. It is imperative that the shielding gas be clean and dry.

COMMENTARY ON TECHNIQUES

The practicality of multi-pass welding will depend upon many factors in each individual application. Multi-pass welding is usually done with smaller beads deposited at lower heat inputs than would be employed in a single-pass. This procedure is used when there is a need for rapid cooling in the heat affected zone and weld toughness which develops in a multi-pass weld deposit resulting from grain refinement and the tempering effect of stringer beads. The desirability of multi-pass welding and the finesse with which it must be applied is judged from the weldability of the steel and the toughness estimated to be required in the weld joint area. Small beads are more susceptible to stress cracking and cause more distortion than-large beads. Stress cracking and distortion can be minimized by using procedures such as back stepping, alternating the stringer beads, etc.

The purpose of minimizing weaving motion is to obtain a reasonably fast travel speed and, thus, avoid an excessively high heat input.

The maximum temperature attained and the length of time at temperature is not only dependent upon the welding process employed, but also the technique exercised by the welder.

Some fabricators insist on welding with high heat inputs in order to deposit larger beads and, thus, more quickly accomplish the welding of a particular joint.

The grains will be much coarser in a large, single-pass weld made at slow speed than in a thin single bead deposited at high speed. It is better to maintain preheat and inter-pass temperatures within recommended limits and to use higher welding current and fast travel. Coarse grains are undesirable because they lack ductility and impact strength. This effect is especially pronounced where each bead is the full width of the groove.

Craftsmanship Expectations for Welding Projects

The student should complete the following tasks prior to welding.

1. Thoroughly read each drawing.
2. If you are having problems understanding the drawing review the blueprint reading videos.
3. Make a cutting list for each project. Cut at least two project assemblies of metal at a time. This will save a great amount of time.
4. Assemble the welding projects per drawing specifications.
5. Review the Welding Procedure portion of the prints to review welding parameter information.
6. See the instructor for the evaluation.

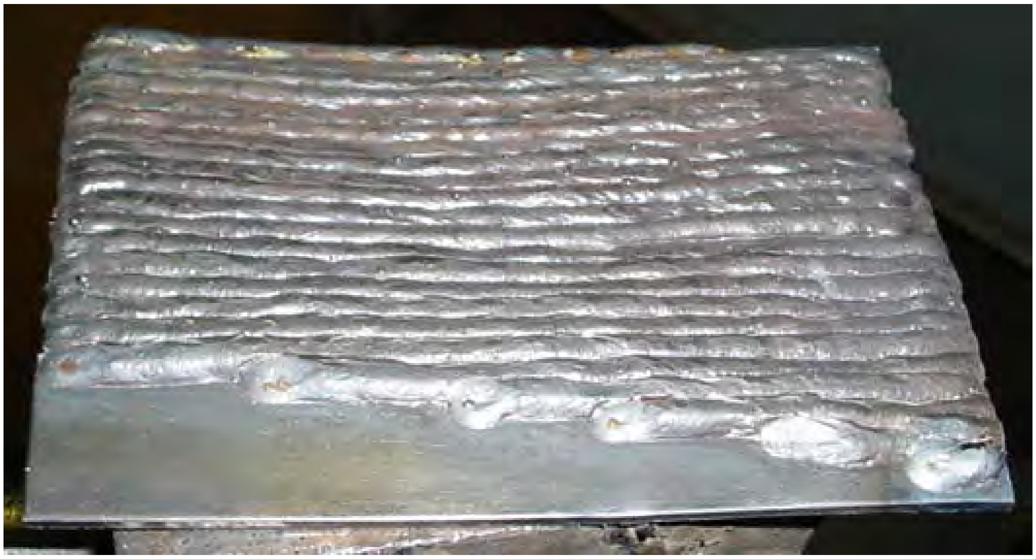
Factors for grading welding projects are based on the following criteria:

Metal Preparation	**Project Layout**	**Post Weld Clean-up**
Oxyacetylene Cut quality	Accurate (+/- 1/16")	Remove Slag/Spatter
Grind all cut surfaces clean	Limit waste	Remove sharp edges

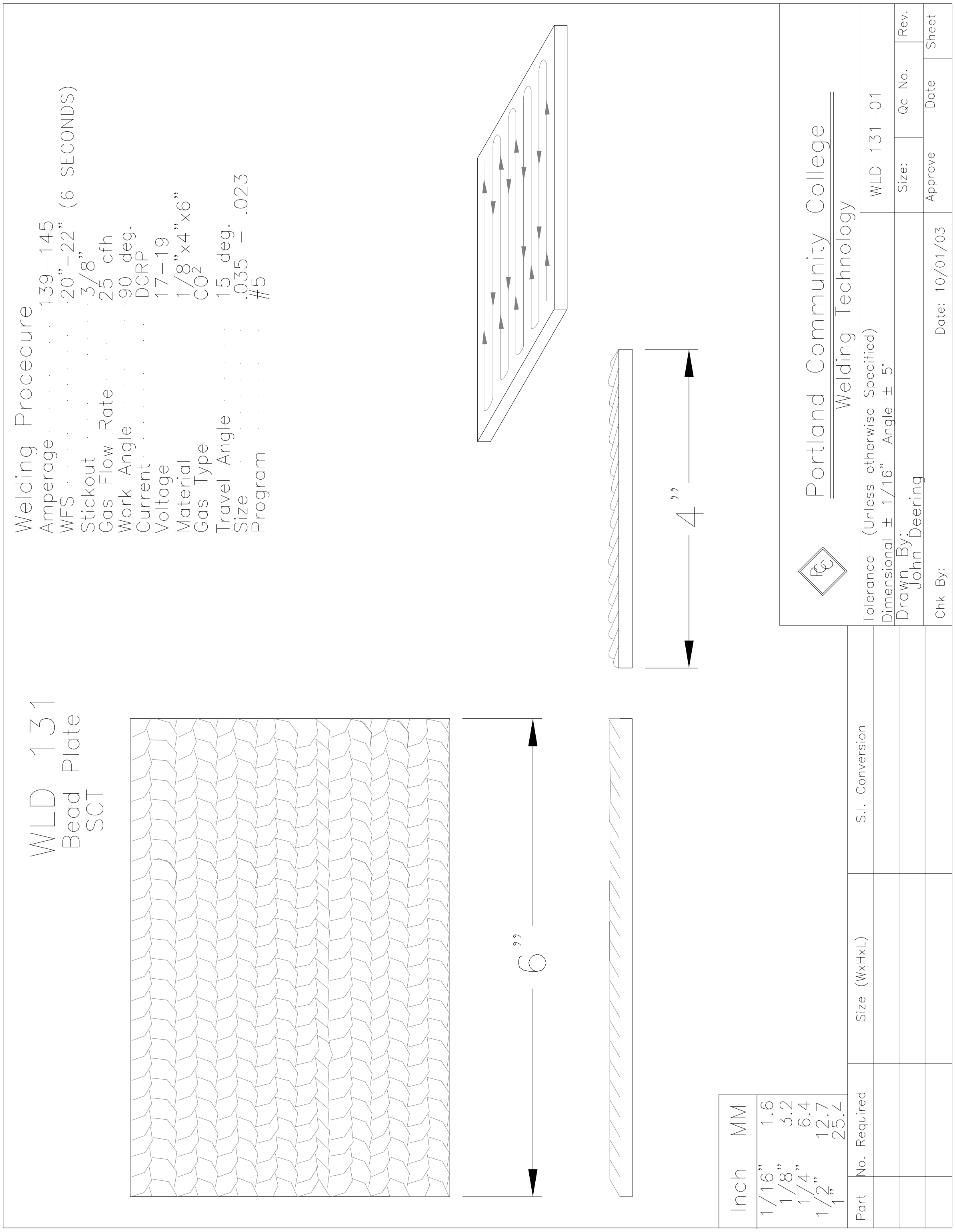
Weld Quality per AWS D1.1

VT Criteria	Cover Pass
Reinforcement (groove welds)	Flush to 1/8"
Fillet Weld Size	See specification on drawing
Undercut	1/32" maximum depth
Weld Contour	Smooth Transition
Penetration	N/A
Cracks	None Allowed
Arc Strikes	None Allowed
Fusion	Complete Fusion Required
Porosity	None Allowed
Overlap	None Allowed

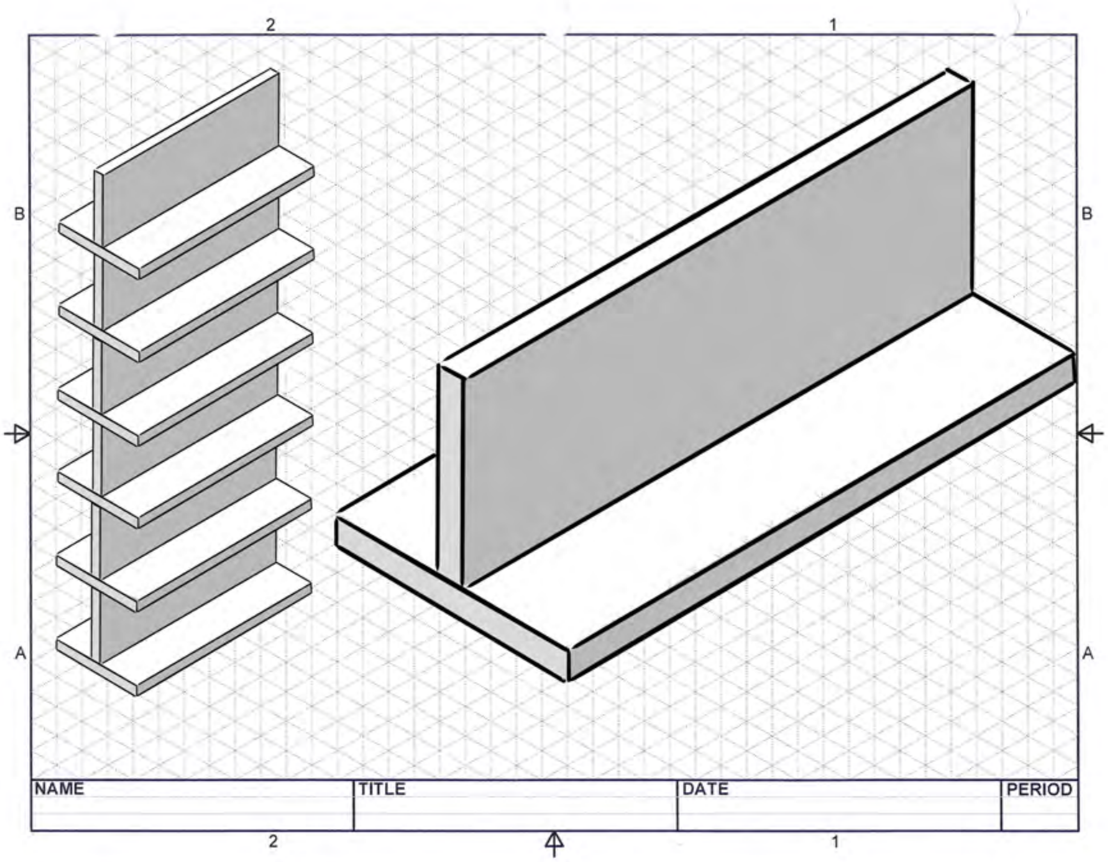
Gas Metal Arc Welding Bead Plate   Project #1



- The above picture is an example of several weld "beads" laid down side by side in a tight pattern. This is a bead plate.
- The purpose of the bead plate is to get the welder aquatinted with a new process and/or to help the welder become comfortable with new machine settings.
- The drawing on the following page is of a bead plate. Notice how you have three views of the bead plate showing the welds from the Top View, Front View and the Side View. To the left of the three views of the bead plate there is a three dimensional view of the bead plate. In the 3-D view the welder is given instruction on what the procedure is for laying down the welds. According to the 3-D view the welds should be put in first from left to right and than from right to left. Following this procedure will help to eliminate distortion and minimize arc blow.
- The following projects each will be accompanied by a picture of what the project should look like when welded out. If you are not familiar with blueprints this is a good time to compare drawings to actual finished projects. If you have any questions about the projects to be welded see your instructor before you proceed.


WLD 131
Bead Plate
SCT
Welding Procedure
Amperage 139-145
WFS 20"-22" (6 SECONDS)
Stickout 3/8"
Gas Flow Rate 25 cfh
Work Angle 90 deg.
Current DCRP
Voltage 17-19
Material 1/8"x4"x6"
Gas Type CO2
Travel Angle 15 deg.
Size .035 - .023
Program #5
6"
4"
Inch MM
1/16" 1.6
1/8" 3.2
1/4" 6.4
1/2" 12.7
1" 25.4
Part
No. Required
Size (WxHxL)
S.I. Conversion
Portland Community College
Welding Technology
Tolerance (Unless otherwise Specified)
Dimensional ± 1/16" Angle ± 5°
Drawn By: John Deering
Chk By:
Date: 10/01/03
WLD 131-01
Size:
Qc No.
Rev.
Approve
Date
Sheet

Gas Metal Arc Welding T-Joint 1F, 2F, 3F, 4F Project #3



- Produce a T-Joint in all positions.
- Tack up multiple T-joints at one time. Weld both sides of each weldment. After each side has been welded, stack the T-Joints as shown in the drawing above to provide more T-Joints to practice on.
- The joints should be practiced as long as it takes to produce high quality welds on a consistent basis. A high quality weld has a uniform appearance, equal legs, straight lines at the toe, and a flat face
-

Gas Metal Arc Welding Horizontal T-Joint 1F Project #2

- To weld the flat position t-joint you will need to first tack the pieses at a 90º angel in relation to each other. Once you have the project tacked together take it to your instructor for his approval of the fit up **before** you weld the project.
- As you are welding the project the nozzle of the Welding gun should be at a 90º angle to the perpendicular and the travel angel should be about 15º. The key to a quality weld is consistency. As you travel across the plate, be consistent in the distance from the nozzle to the work. Be consistent in the travel speed, and keep the Welding gun at the same angel from the beginning of the weld to the end of the weld.
- If you are not sure what some of the prints are weld symbols mean you will find more information relating to this subject in the "Welding Principles and Applications" textbook in chapter 18.

Gas Metal Arc Welding Horizontal T-Joint 2F Project #2

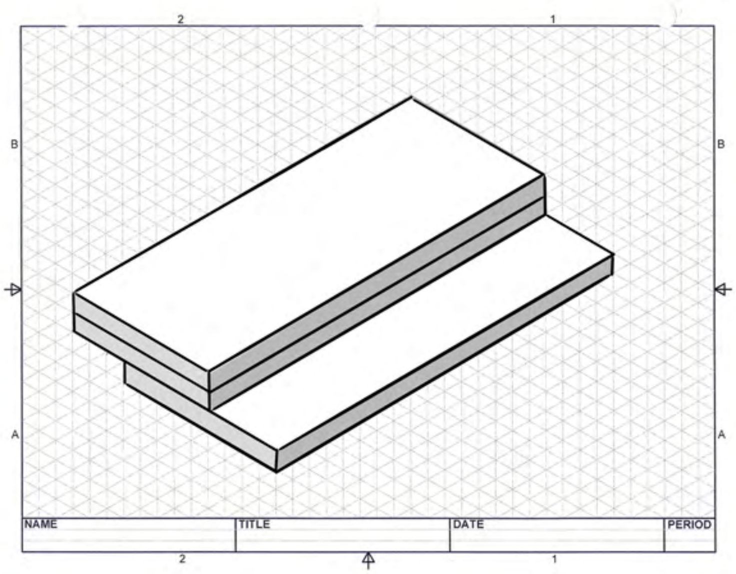
- To weld the Horizontal "T" (which is shown in the picture above and also in the print on the following page) you will need to first tack the three pieces together as indicated in the print. Make sure all of the parts are at a 90º angel in relation to each other. Once you have the project tacked together take it to your instructor for his approval of the fit up **before** you weld the project.
- As you are welding the project the nozzle of the Welding gun should be at a45º angle to the perpendicular and the travel angel should be about 15º. The key to a quality weld is consistency. As you travel across the plate, be consistent in the distance from the nozzle to the work. Be consistent in the travel speed, and keep the Welding gun at the same angel from the beginning of the weld to the end of the weld.
- If you are not sure what some of the prints are weld symbols mean you will find more information relating to this subject in the "Welding Principles and Applications" textbook in chapter 18.

Gas Metal Arc Welding Vertical T-Joint 3F (vertical up and vertical down) Project #3

- The Vertical Down position is often used when welding material that is thin gauge. By using the downward travel motion the welder applies less heat to the pieces being welded.
- With the Welding gun pointed upward as shown in the picture, start the weld and travel from top to bottom. Watch the weld bead and the pieces being welded for signs that you are moving to slowly. If it appears that the metal is about to melt through pick up the travel speed.
- The Short Circuit Transfer (SCT) and Surface Tension Transfer (STT) Welding methods have a very low heat input and in most cases Vertical up is the preferred method of Welding with this process. However in some cases Vertical Down will be required due to a part being very thin or the need to control heat distortion.
- Once you have successfully completed this project in the Vertical Down do the same project again, this time starting from the bottom and going up. This is the Vertical up Welding position.
- When running the first pass (Root Pass) of the Vertical up Weld you should move the gun slightly from left to right as you Weld to better spread the Weld to both sides of the Weld joint.

- The Overhead weld is applied in much the same way as the Horizontal "T" fillet weld. Keeping the Welding Gun at about 45º to the perpendicular and at about a 15º forward travel angel move the gun across the weld joint while watching the weld puddle. Make sure that you are seeing the puddle of molten metal spread out and flow in smoothly at the edges. The force of the arc coming off of the electrode (wire) should also be utilized in helping to keep the weld in place and to spread the molten puddle.
- As you progress across the weld pay attention to your travel speed and the position that you are holding your gun. By keeping travel speed and gun angel the same all the way across the weld you will end up with a clean and consistent looking weld.
- The Weld symbol on the following print calls for a single Weld pass to be applied at each of the Weld joints on the print. After you have finished putting in the first Weld joint show the Weld to your instructor before you continue on to the other Welds.

Gas Metal Arc Welding - Lap Joint 1F, 2F, 3F, 4F Project #3



- Produce a lap joint in all positions.
- Sizes will vary with the sheet metal available.
- Sheet stock should be stacked as shown in the drawing and photos above when performing the horizontal lap joint. This will give you the opportunity to weld a small and medium sized fillet. For all other positions a single thickness is all that is required.
- Use similar technique to the horizontal t-joint for the double thickness and a simple forward stop or forward /slightly back for the single thickness.

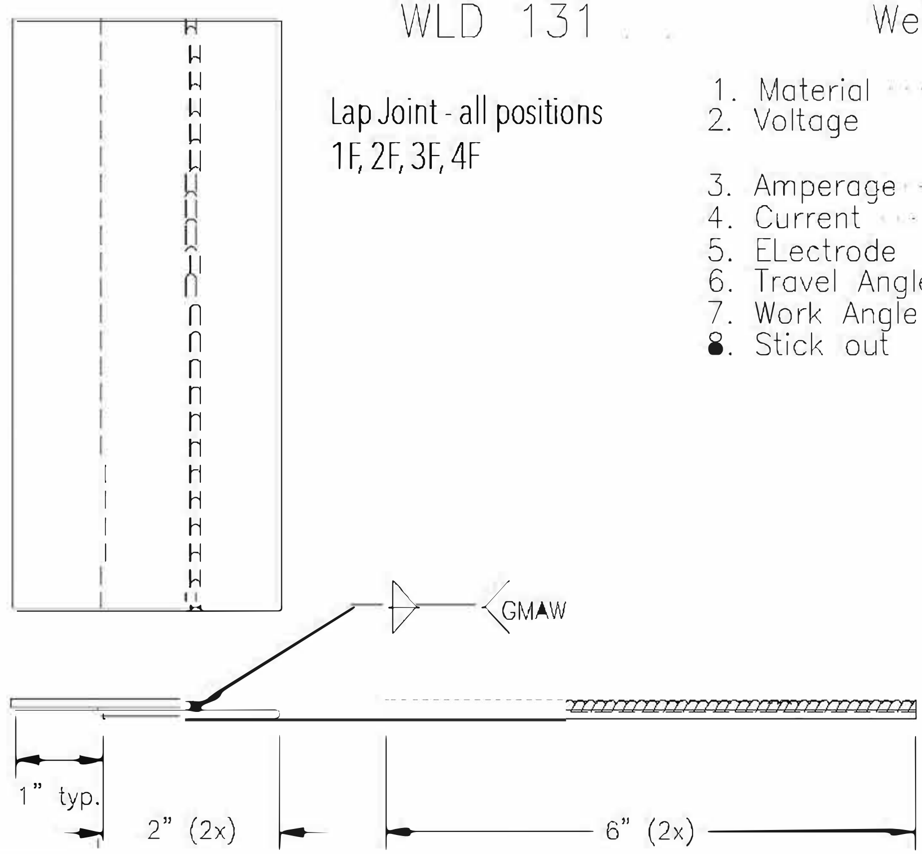
WLD 131

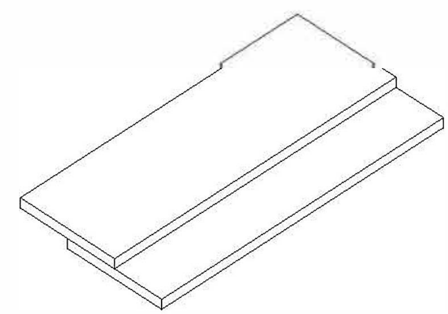
Lap Joint - all positions
1F, 2F, 3F, 4F

Welding Procedure

1. Material .... 12 Gauge–2"x6"
2. Voltage 17–19

3. Amperage 90–135
4. Current .... DCRP
5. ELectrode ER70S-6
6. Travel Angle .... 35°–40°
7. Work Angle .... 45°
8. Stick out .... 3/8"





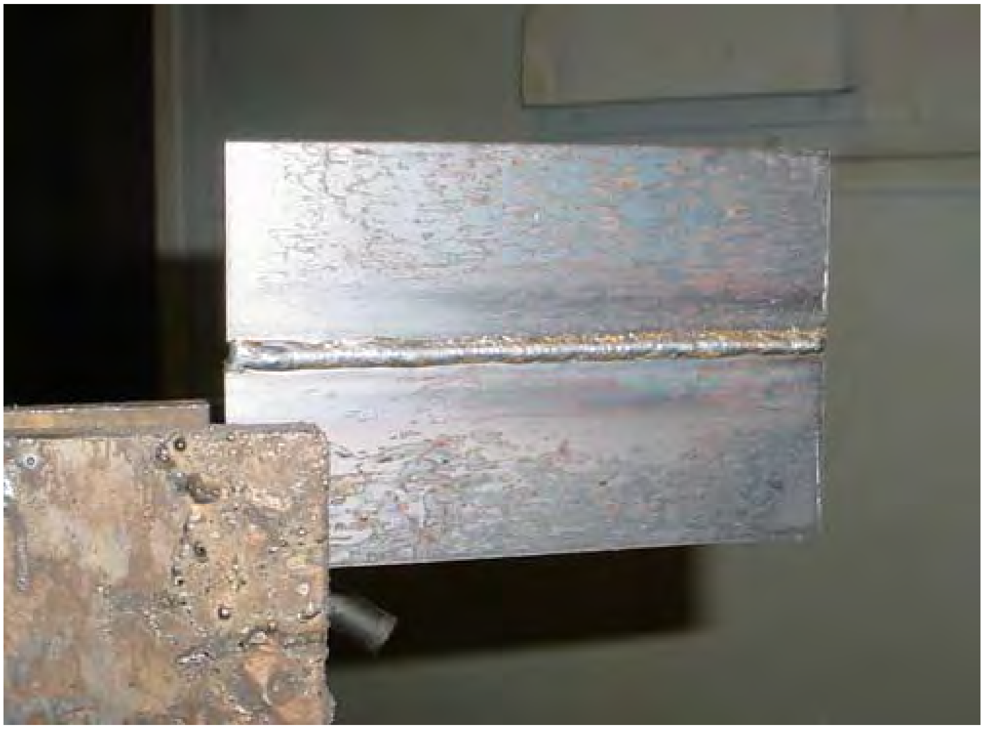
Inch	MM
1/16"	1.6
1/8"	3.2
1/4"	6.4
1/2"	12.7
1"	25.4

Part	No. Required	Size (TxWxL)	S.I. Conversion

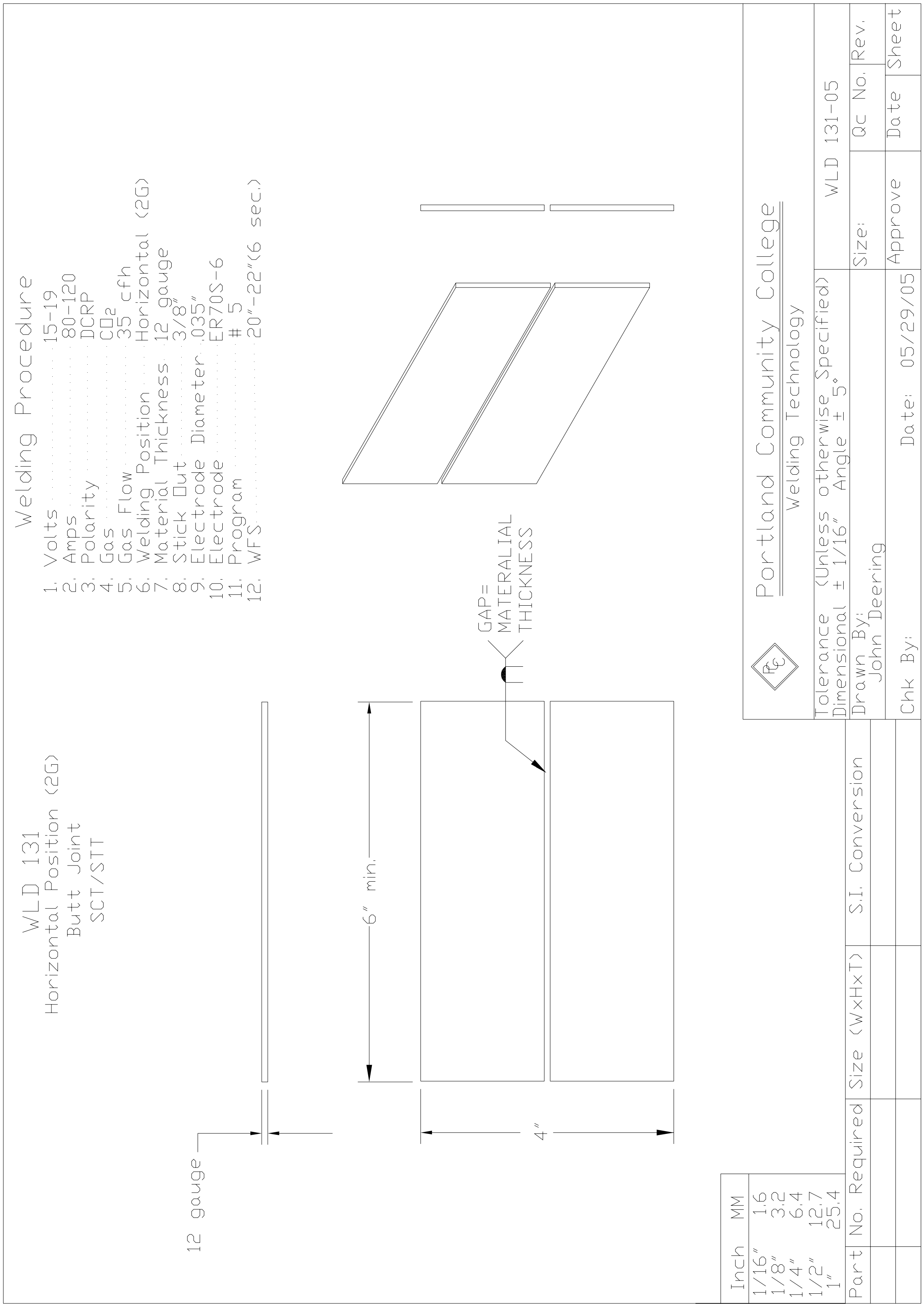
Portland Community College
Welding Technology

Tolerance (Unless otherwise Specified)
Dimensional ± 1/16" Angle ± 5°
Drawn By:
John Deering
Chk By: TANNER SCOTT Date: 12/15/15

WLD 131–20
Size: Qc No. Rev.
Approve Date Sheet

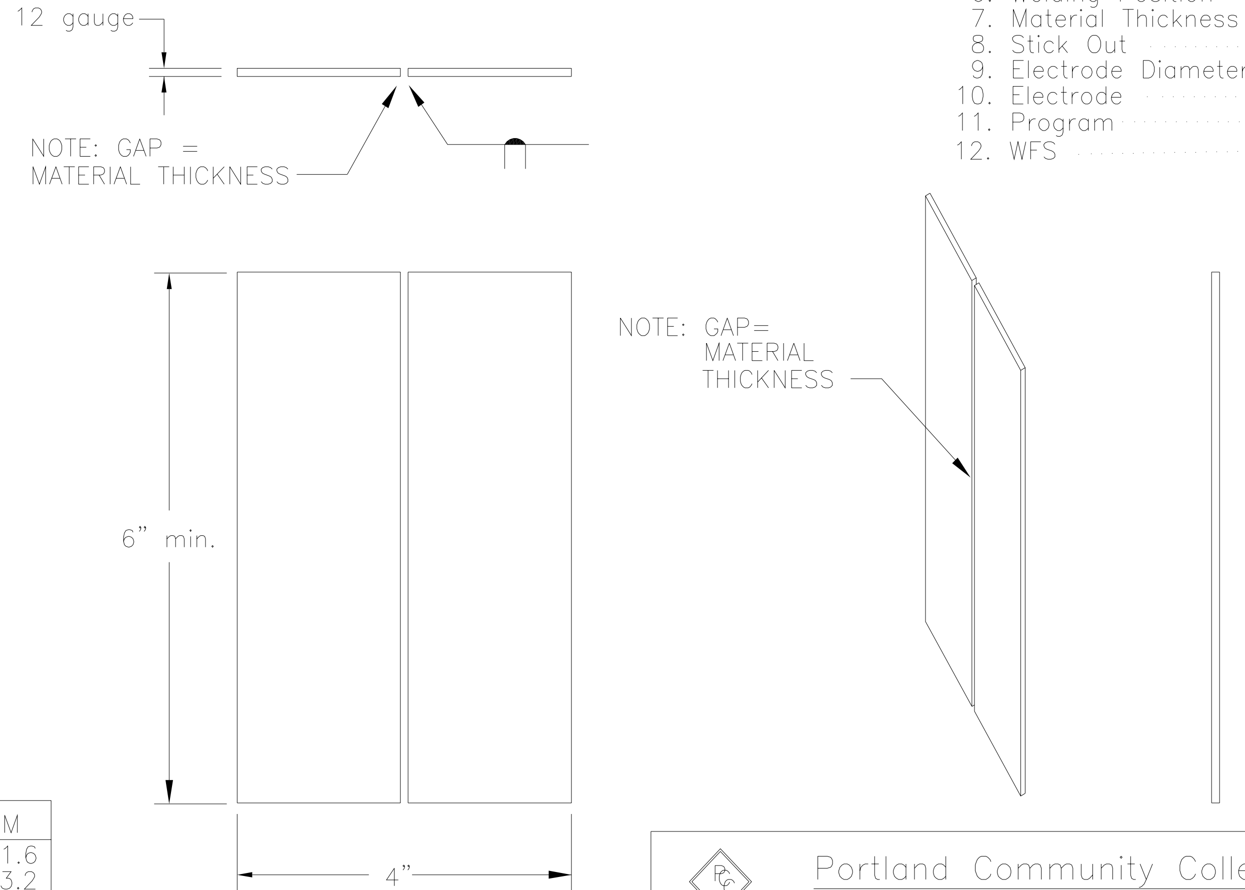


- Welding in the 2-G position will require that you have the welding gun tilted upward approximately 15°. This will aid you in keeping the weld puddle from sagging along the bottom edge. The force of the arc coming off of the end of the electrode (wire) will push the molten metal puddle upward due to the angel of the gun.
- The drawing calls for a gap (see the weld symbol) that is equal in size to the thickness of the metal. In this case the metal is 12 gage so the gap would be .109375 or 7/64th which is just slightly larger then 1/6th of an inch.
- Practice running the root pass with about a 15° travel angel and a 15° upward angel. As you make the practice weld you should adjust your travel speed until you see the weld puddle penetrating the gap and filling in the edges but not rolling over the bottom edge of the gap.
- After making the weld check the back of the piece. You should see the gap completely filled in with the weld metal equal to or slightly greater then the surface of the piece you are Welding. The weld can be slightly convex (no more then 1/6th of an inch) but it should not be concave.
- If you can not get the Weld to penetrate through the gap try opening up the spacing of the gap slightly until you are getting good Weld penetration on the back of the project.


WLD 131
Horizontal Position (2G)
Butt Joint
SCT/STT
Welding Procedure
1. Volts 15-19
2. Amps 80-120
3. Polarity DCRP
4. Gas CO2
5. Gas Flow 35 cfh
6. Welding Position Horizontal (2G)
7. Material Thickness 12 gauge
8. Stick Out 3/8"
9. Electrode Diameter .035"
10. Electrode ER70S-6
11. Program # 5
12. WFS 20"-22"(6 sec.)
GAP=
MATERALIAL
THICKNESS
6" min.
4"
12 gauge
Portland Community College
Welding Technology
Tolerance (Unless otherwise Specified)
Dimensional ± 1/16" Angle ± 5°
WLD 131-05
Drawn By:
John Deering
Size:
Qc No.
Rev.
Chk By:
Date: 05/29/05
Approve
Date
Sheet
Inch MM
1/16" 1.6
1/8" 3.2
1/4" 6.4
1/2" 12.7
1" 25.4
Part
No. Required
Size (WxHxT)
S.I. Conversion

- Welding in the32-G position will require that you have the welding gun tilted upward approximately 15°. This will aid you in keeping the weld puddle from pilling up or falling out at the bottom edge. The force of the arc coming off of the end of the electrode will push the molten metal puddle upward due to the angel of the gun.
- The drawing calls for a gap (see the weld symbol) that is equal in size to the thickness of the metal. In this case the metal is 12 gage so the gap would be .109375 or 7/64th which is just slightly larger then 1/6th of an inch.
- Practice running the root pass with about a 15° upward angel, this will also be known as your travel angel when working in the vertical position. As you make the practice weld you should adjust your travel speed until you see the weld puddle penetrating the gap and filling in the edges but not rolling over the bottom edge of the gap.
- After making the weld check the back of the piece. You should see the gap completely filled in with the weld metal equal to the height of the surface. The weld can be slightly convex (no more then 1/6th of an inch) and should not be concave.

WLD 131
Vertical Position (3G)
Butt Joint
SCT/STT



Welding Procedure

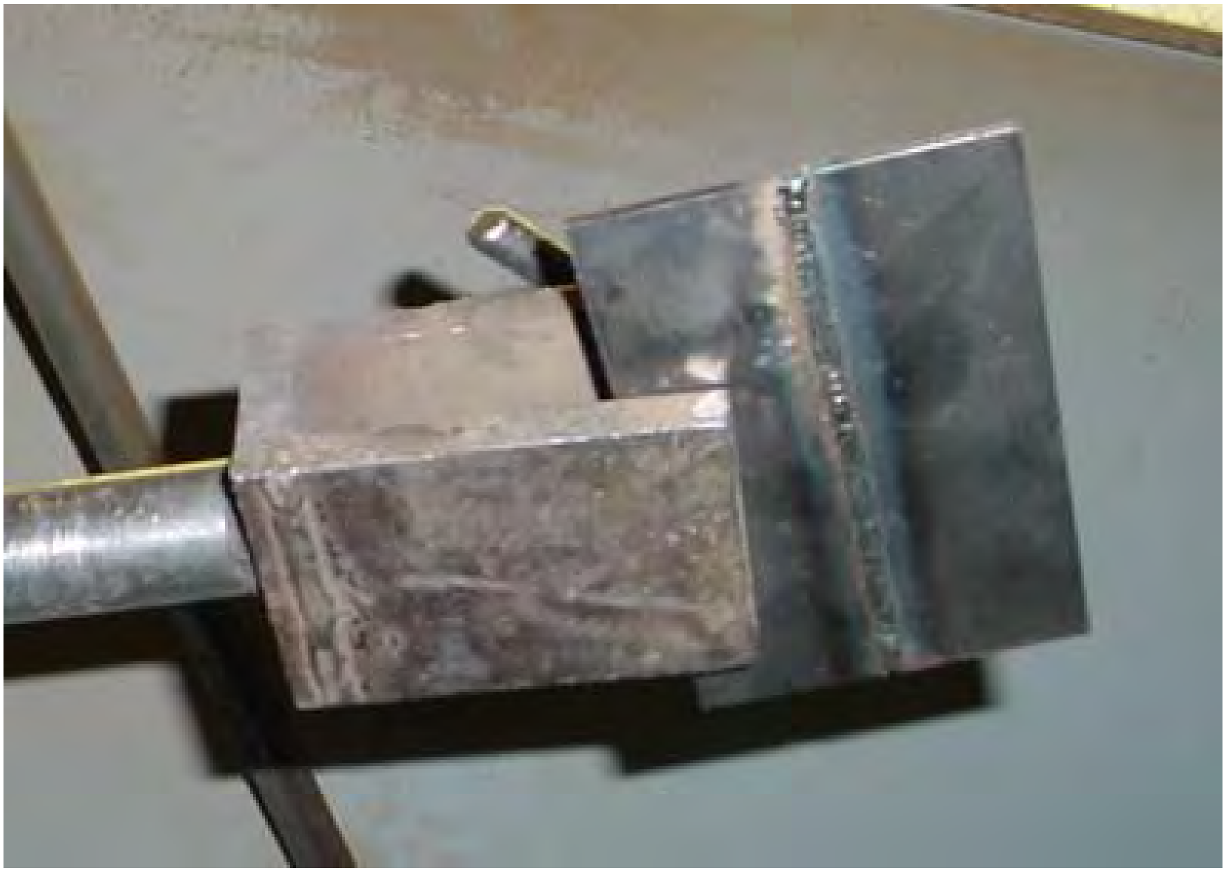
1. Volts 15–19
2. Amps 80–120
3. Polarity .... DCRP
4. Gas .... CO_2
5. Gas Flow .... 35 cfh
6. Welding Position .... Vertical (3G)
7. Material Thickness .... 12 gauge
8. Stick Out .... 1/4"
9. Electrode Diameter .... .035"
10. Electrode ER70S–6
11. Program .... # 5
12. WFS .... 20"–22"(6 sec.)

Inch	MM
1/16"	1.6
1/8"	3.2
1/4"	6.4
1/2"	12.7
1"	25.4

Part	No. Required	Size (WxHxT)	S.I. Conversion

Portland Community College
Welding Technology

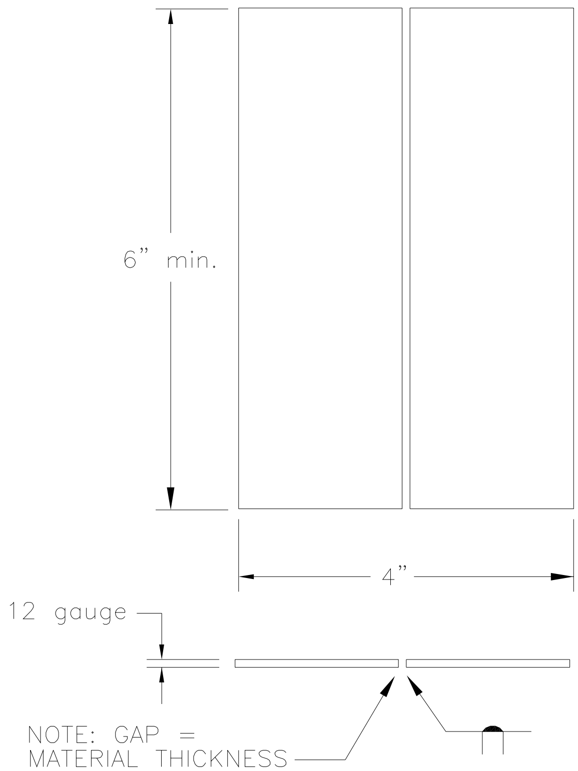
Tolerance (Unless otherwise Specified) Dimensional ± 1/16" Angle ± 5°	WLD 131–06		
Drawn By: John Deering	Size:	Qc No.	Rev.
Chk By: Date: 05/29/05	Approve Date		Sheet



- Overhead welding is accomplished in much the same manner as welding in the flat position. The force of the arc coming off of the electrode (wire) actually helps to hold the molten metal in place until it starts the cooling process. The arc force also helps to spread out the weld as it is being applied.
- First find a comfortable position and decide which direction (left to right or right to left) works best for you when welding. Remember to be consistent as you travel across the weld joint always keeping the gun distance and angel the same.

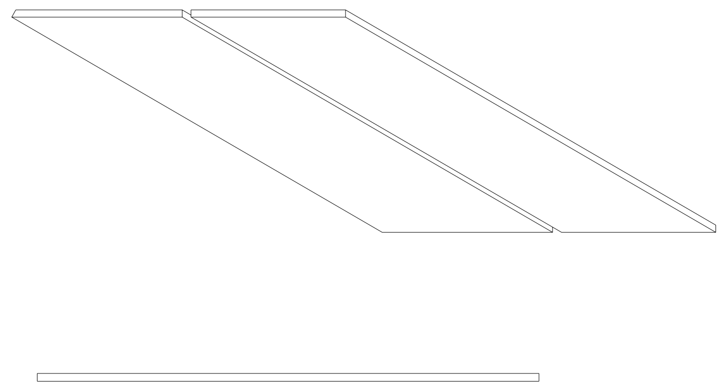
WLD 131

Overhead Position (4G)
Butt Joint
SCT/STT



Welding Procedure

1. Volts 15–19
2. Amps 80–120
3. Polarity .... DCRP
4. Gas .... CO_2
5. Gas Flow .... 20 cfh
6. Welding Position .... Overhead (4G)
7. Material Thickness .... 12 gauge
8. Stick Out .... 1/4”
9. Electrode Diameter .... .035”
10. Electrode ER70S–6
11. Program .... #5
12. WFS .... 20”–22”(6 sec.)



Inch	MM
1/16”	1.6
1/8”	3.2
1/4”	6.4
1/2”	12.7
1”	25.4

Part	No. Required	Size (WxHxT)	S.I. Conversion

Portland Community College
Welding Technology

Tolerance (Unless otherwise Specified) Dimensional ± 1/16” Angle ± 5°	WLD 131–07		
Drawn By: John Deering	Size:	Qc No.	Rev.
Chk By: Date: 05/29/05	Approve	Date	Sheet

Information Sheet
Mild Steel Spray Arc Welding

The spray arc section of this packet will require the "welder" to follow the welding procedure on the Blue Print. The following terms will be defined to clarify the procedure.

Program mode	***CV MIG GMAW Gas Shielded***
Volts	Read off machine when the machine is on but there is no welding. This is referred to as *Open Circuit Voltage* (OCV).
WFS	**read directly off the LN7 wire feeder**
Shielding Gas	**98% Argon and 2% Oxygen**
Special Note	**All the knobs on this equipment are ultra-sensitive. Any slight movement of the knobs will result in a large adjustment on the equipment.**

GMAW Spray Transfer T Joint (2F) Project #21

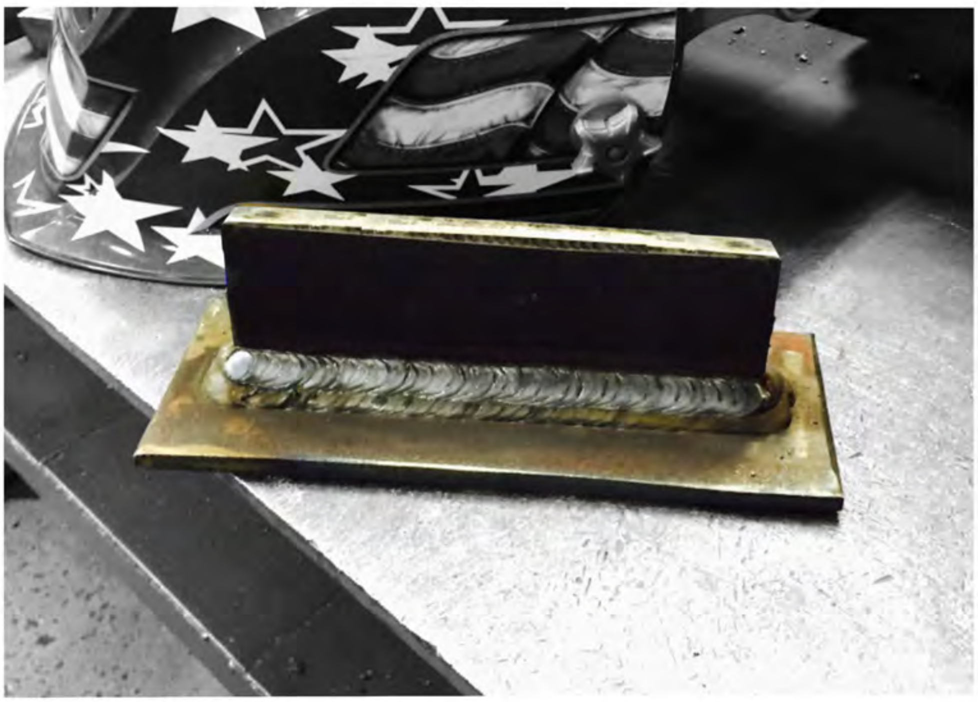
Technique

Use a stringer bead technique and push gun progression.

Welding Sequence

Remember when welding in the horizontal position to start your welding sequence from the horizontal leg of the joint and place the weld beads "bottoms up" to the vertical leg of the joint.

Wrap the weld around the corner. Do not stop or restart at the corner.

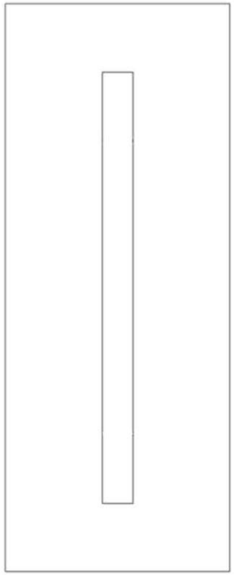


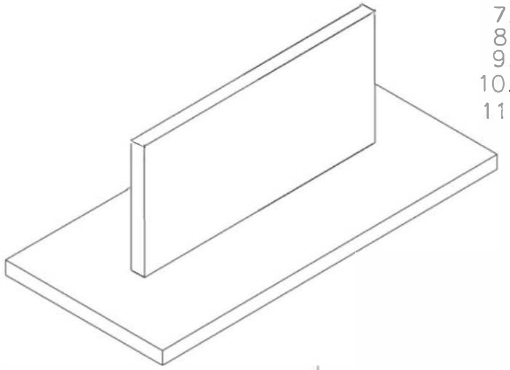
VT Criteria	Student Assessment		Instructor Assessment	
Reinforcement				
Undercut				
Weld Bead Contour				
Penetration				
Cracks				
Arc Strikes				
Fusion				
Porosity				
	Grade	Date	Grade	Date

WLD 132

GMAW Spray Mild Steel

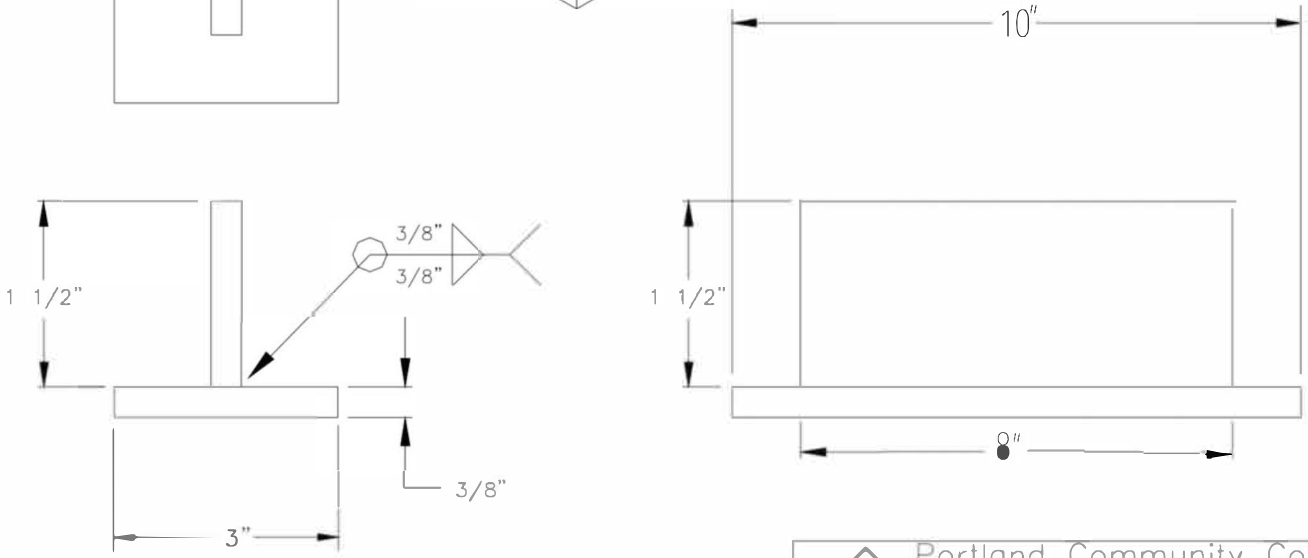
Horizontal Position T-Joint (2F)





Welding Procedure

1. Volts — 24-30
2. WFS — 380-440
3. Polarity — DCRP
4. Gos — 98% Argon, 2% Oxy
5. Gos Flow — 45 cfh
6. Welding Position — Horizontal (2F)
7. Material Thickness — 3/8" Plate
8. Stickout — 3/4"
9. Electrode Diameter — .035"
10. Electrode — ER70S-6
11. V350Pro Program — CV Mig GMAW Gos Shielded



Inch	MM
1/16"	1.6
1/8"	3.2
1/4"	6.4
1/2"	12.7
1"	25.4

Part	No. Required	Size (TxWxL)	S.I. Conversion

Portland Community College

Welding Technology

Tolerance (Unless otherwise Specified)
Dimensional ± 1/16" Angle ± 5°

Drawn By: John Deering

Chk By: Date:

WLD 132-01

Size:	Qc No.	Rev.
Approve	Date	Sheet

GMAW Spray Transfer Groove Weld (2G) Project #22

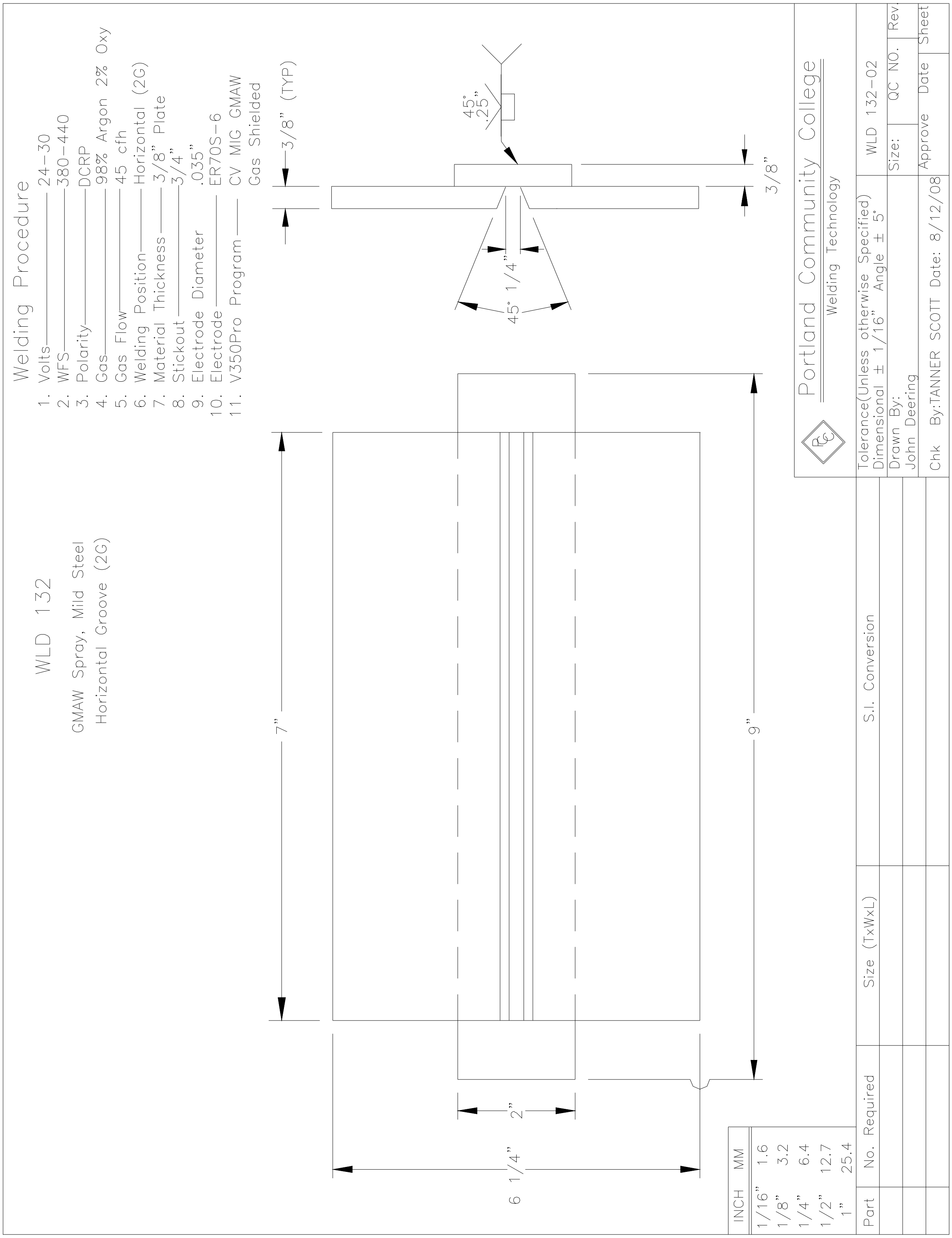
Technique

Use a stringer technique and push gun progression.

Welding Sequence

1. Root Pass – travel slow enough to capture all three plates. BUT travel fast enough so the weld does not roll where the parent metal intersects with the back strap.
2. Fill passes. Start with the bottom pass and keep welds in line with the shoulder of the bevel.
3. Cover passes (finish beads) starting with the bottom pass first, make sure to travel fast enough to prevent overlap (cold roll).

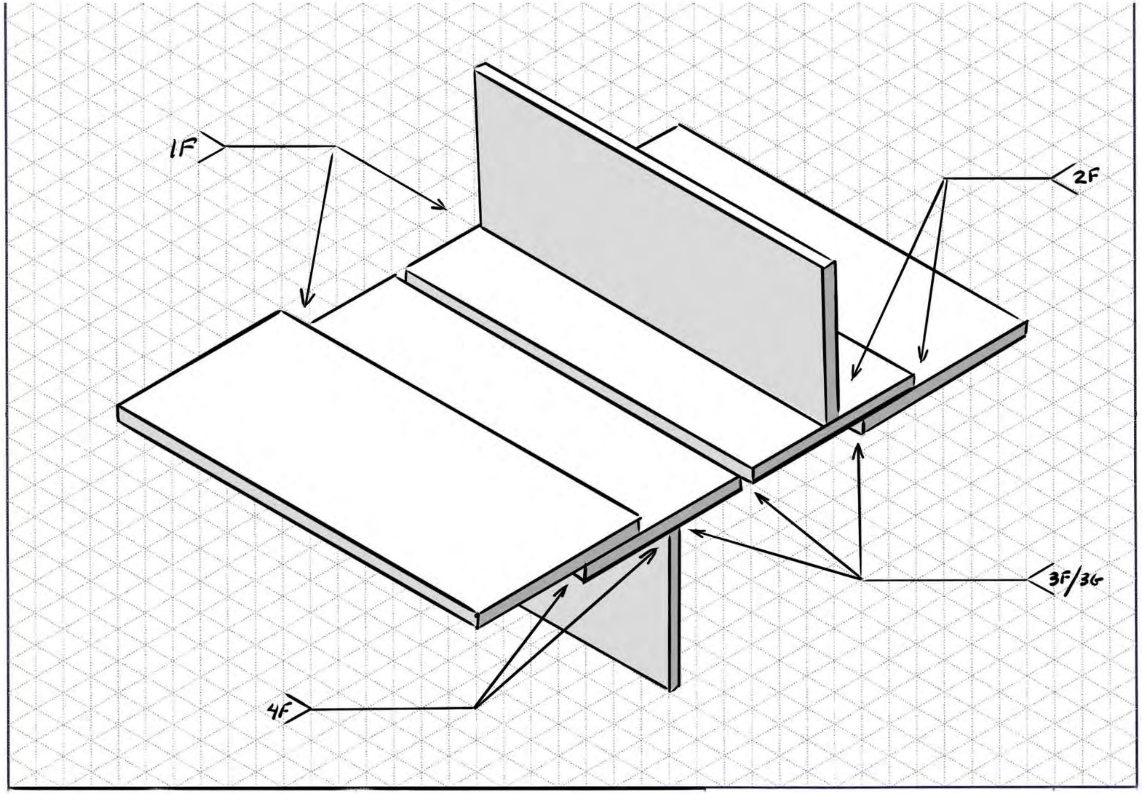
VT Criteria	Student Assessment	Instructor Assessment
Reinforcement		
Undercut		
Weld Bead Contour		
Penetration		
Cracks		
Arc Strikes		
Fusion		
Porosity		
Bend Test per AWS D1.1		
	Grade Date	Grade Date


WLD 132
GMAW Spray, Mild Steel
Horizontal Groove (2G)
Welding Procedure
1. Volts — 24-30
2. WFS — 380-440
3. Polarity — DCRP
4. Gas — 98% Argon 2% Oxy
5. Gas Flow — 45 cfh
6. Welding Position — Horizontal (2G)
7. Material Thickness — 3/8" Plate
8. Stickout — 3/4"
9. Electrode Diameter — .035"
10. Electrode — ER70S-6
11. V350Pro Program — CV MIG GMAW Gas Shielded
3/8" (TYP)
45°
.25"
1/4"
45°
3/8"
7"
9"
2"
6 1/4"
Portland Community College
Welding Technology
Tolerance(Unless otherwise Specified)
Dimensional ± 1/16" Angle ± 5°
Drawn By:
John Deering
Chk By:TANNER SCOTT Date: 8/12/08
WLD 132-02
Size:
QC NO.
Rev.
Approve
Date
Sheet
INCH MM
1/16" 1.6
1/8" 3.2
1/4" 6.4
1/2" 12.7
1" 25.4
Part
No. Required
Size (TxWxL)
S.I. Conversion

Part 1 of 2

WLD 131
Final Exam
Short Arc

Notes: Unless otherwise specified
1. Drawn per current applicable ANSI & Industry standards.



Inch	MM
1/16"	1.6
1/8"	3.2
1/4"	6.4
1/2"	12.7
1"	25.4

Part	No. Required	Size (WxHxL)	S.I. Conversion

PORTLAND COMMUNITY COLLEGE
Welding Technology

Tolerance (Unless otherwise Specified)
Dimensional ± 1/16" Angle± 5°

WLD 131 Final Exam

Drawn By:
John Deering

Size: | QC NO. | Rev.

Chk by: | Date:

Approved | Date | Sheet

GMAW Worksheet

1. What components make up a GMA welding system?

2. Why must GMA welders have a 100% duty cycle?

3. What can happen if rollers of the wrong shape are used on aluminum wire?

4. Where is the drive motor located in a pull-type wire-feed system?

5. How is the wire-feed speed changed with a linear feed system?

6. What type of liner should be used for aluminum wire?

Review Questions

1. What items make up a basic semiautomatic welding system?

2. What must be done to the shielding gas cylinder before the valve protection cap is removed?

3. Why is the shielding gas valve “cracked” before the flowmeter regulator is attached?

4. What causes the electrode to bird-nest?

5. Why must all fittings and connections be tight?

6. What parts should be activated by depressing the gun switch?

7. What benefit does a welding wire's cast provide?

8. What can be done to determine the location of a problem that stops the wire from being successfully fed through the conduit?

9. What are the advantages of using a feed roller pressure that is as light as possible?

10. Why should the feed roller drag prevent the spool from coasting to a stop when the feed stops?

11. Why must you always wind the wire tightly into a ball or cut it into short lengths before discarding it in the proper waste container?

12. What are the advantages of using CO_2 for making GMA welds on steel?

13. What is mill scale?

14. What type of porosity is most often caused by mill scale?

15. What should the welder watch if the view of the weld is obstructed by the shielding gas nozzle?

16. When making a vertical weld and it appears that the weld metal is going to drip over the shelf, what should you do?

17. What are the advantages of making vertical down welds?

WELDING TERMS

NAME: ________________________________ DATE: ______________________

DIRECTIONS: Define the terms listed below. Refer to the "Vocabulary" Information Sheet. Failure to complete to the instructor's satisfaction, will require additional study before attempting to re-do this Work Sheet. USE PENCIL

1. Spatter

2. Wire Conduit

3. Flow Meter

4. Regulator

5. Voltage

6. Welding Current

7. Zero Arc Length

8. Plus Arc Length

9. Minus Arc Length

10. Work Angle

Math On Metal

Adding Decimals

Sometimes, print or metal dimensions or other measurements may come in decimal rather than fraction form. We can usually use a calculator, but we should be able to able to add and subtract decimals in a pinch. Try working these problems by hand and them check them by calculator. Better yet, make an educated guess of approximately how big the answer will be before you do any calculations!

When adding decimals, these are the things to keep in mind:

1. The decimal points must line up.
2. A whole number has a decimal point at its right.
3. You may add zeros to the right of the decimal point as place-holders to help keep the columns straight and decimal places lined up correctly
4. The decimal point in the answer goes directly below the other decimal points.

Example: Add 3 + 5.94 + 2.08 =

$$\begin{array}{r} 3.00 \\ 5.94 \\ \underline{2.08} \\ 11.02 \end{array}$$

Add, then check your answers with a calculator.

1. .8 + .095 + .47 =
2. 5.6 + 25 =
3. 99 + 3.1 + 6.002 =
4. 9.04 + 2.085 =
5. 0.273 + 10.9084 =
6. 46.395 + .0005 =
7. 28 + .087 + 5.92 =
8. 22.19 + .003 =

Subtracting Decimals

Sometimes, print or metal dimensions or other measurements may come in decimal rather than fraction form. We can usually use a calculator, but we should be able to able to add and subtract decimals in a pinch. Try working these problems by hand and them check them by calculator. Better yet, make an educated guess of approximately how big the answer will be before you do any calculations!

When subtracting decimals, these are the things to keep in mind:

1. The decimal points must line up.
2. A whole number has a decimal point at its right.
3. Add zeros as necessary to the far right side of decimals so that each decimal has the same number of decimal places, all lined up correctly
4. Subtract just as you would with whole numbers.
5. The decimal point in the answer goes directly below the other decimal points in the problem.

Example: 23 - 6.038

$$\begin{array}{r} 23.000 \\ \underline{-6.038} \\ 16.962 \end{array}$$

Add, then check your answers with a calculator.

1.	4.5 - 3.72 =	2.	.942 - .1275 =
3.	4 - 2.86 =	4.	93.8 - .6776 =
5.	.70 - .054 =	6.	89 - .0003 =
7.	1 - .036 =	8.	4.45 - .0025 =

Converting Decimal Inches to the Nearest Sixteenth of an Inch

Sometimes you need to convert decimal inch measurement to inches and sixteenths of an inch:

For example: Suppose you want to convert a measurement of 2.25" in a dimension manual to a measurement of inches and sixteenths of an inch.

To do that you (1) write **2** down on your paper as the number of whole inches;

(2) then you enter the rest of the number **.25** into your calculator.

Remember to put in the decimal point!

.25

(3) Multiply this number by 16; (this is the number of 16th's of an inch that you have.)

.25 x 16 = 4 **or 4/16.** ***Reduce to ¼.*** *Put it together with the* ***2"*** *to get* ***2 ¼"***

Try the following problems, converting the measurement to the nearest 1/16 of an inch:

1. 0.875 inches = _______________
2. 8.4375 inches = _______________
3. 9.0625 inches = _____________
4. 1.5625 inches = _____________

The following is an example of a number that isn't quite so neat as the ones above. It will not come out evenly to a whole number of sixteenths, so you will have to do one more step . . .

Convert 7.395": (1) Write **7** down on your paper as the number of whole inches; then

(2) Enter the rest of the number in your calculator as

.395 (without the 7! BUT <u>WITH</u> THE DECIMAL POINT!)
Notice that this number is not quite so predictable and neat as ".25"

(3) Multiply this number by 16* ***<u>and round your answer off to the nearest whole number</u>***; this is the number of 16th's of an inch that you have.
.395 x 16 = 6.32 = approx. **6 or 6/16**

(4) If possible, reduce this fraction to eighths or fourths, etc. and include the whole number of inches with the answer: **7 3/8 inches**

5. 25.445 inches = _____________

6. 36.955 inches = _____________

7. 48.07 inches = ____________

8. 13.62 inches = ____________

*Note that if you wanted to convert to the nearest 1/8 instead of 1/16, you would multiply by 8 instead of 16, and if you wanted a finer measurement of 32nds, you would multiply by 32 instead of 16. It's that easy!

Review of Fractional Tolerances

This is probably a good time to review fractional tolerances. Remember to add and subtract fractions, they need to have the same denominator (the number on the bottom of the fraction). The GOOD news is that this is pretty easy to find with the denominators we associate with inches: 1/16, 1/8, ¼, ½, etc. The trick is to always choose the larger or largest denominator and change all the other fractions so that they have that largest denominator. When we do this, we must remember to maintain proportionality. We do this by making sure that whatever we have to multiply the bottom of the fraction to get the new denominator is the same number we multiply the top by. *Notice the larger denominator is circled.*

$$\frac{1}{16} + \frac{7}{8} = ?$$

$$\frac{1}{16} + \frac{7_{x2}}{8_{x2}} \qquad \frac{1}{16} + \frac{14}{16} = \frac{15}{16}$$

Try this fractional tolerance:

1. 3 ¼ ± 1/16

   Minimum = ______

   Maximum = ______

The other trick you should remember is that when you are subtracting, sometimes you have to borrow. When you have to do this, it is good to imagine you are cutting one of the whole inches into sixteenths or eighths (whatever the common denominator is) and adding to the fractional part of the mixed number. It will often be the only fractional part. **see below**

Remember that one inch has 16 sixteenths
one inch has 8 eighths
one inch has 4 fourths, etc.

7” ± 1/16” To add is very simple here: 7 + 1/16 = 7 1/16”

To subtract takes a little more work and trickery:

$$\overset{6}{\not{7}}\ \frac{16}{16} - \frac{1}{16} = 6\ \frac{15}{16}$$

Try this fractional tolerance:

2. 24 ± 1/8” *Minimum* = _______

   Maximum = _______

BILATERAL AND UNILATERAL TOLERANCES

Places where we frequently find decimal notation in the shop are blueprints and "spec" sheets. Dimensions and tolerances are often in decimal notation.

There are two different kinds of tolerances used: bilateral and unilateral. Bilateral tolerances are just what they sound like**: two-sided tolerances**.

An example of a dimension with an attached bilateral tolerance is 1.15 mm t.005 mm. Notice that the .005 mm can be either added to get 1.155 for the upper limit (maximum) of acceptable measure, or it can be subtracted to get 1.145 for the lower limit (minimum) of what would be considered an acceptable measure.

A **unilateral tolerance** is just what it sounds like. It is a tolerance on only one side. In other words, the little bit of leeway allowed in measurement **is in only one direction, either larger or smaller.**

For example, a dimension with unilateral tolerance may read like this:

.45 in. + 0 inch
- .0025 inch

What the above notation means is that the dimension can be .0025 inch less than 0.45 inch, but cannot be any greater than .45 inch. The maximum acceptable dimension is 0.45 inch. The minimum acceptable dimension is .45 -.0025 = 0.4475 inch.

So, what does the tolerance notation below mean?

30.75 mm + .002 mm
- O mm

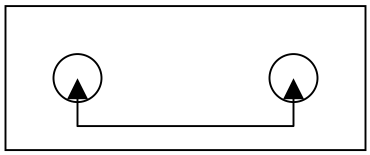
What is its minimum acceptable dimension? What is its maximum acceptable dimension?

Try completing the following chart with minimum and maximum measurements, given the bilateral or unilateral tolerance:

MEASURMENT + TOLERANCE	MINIMUM	MAXIMUM
3.50 t 0.015 mm		
28.01 ±.001 inch		
35.6 mm + 0 -.025		
3.375 in. +.0008 -0		
4.625 in. + 0 -.005		

Can You Tolerate This?

Now we are going to do for decimals what we did for fractions. We are going to calculate tolerances. If you didn't take WLD 113 recently, you might have missed that lesson, so we'll review it here.



23.35 ± .002

Blueprints almost always have tolerances printed on them.* They look something like this: **23.35 ± .002 inches**.

This expression is usually attached to a particular dimension*, like a diameter or length or thickness of an object or, as above, the distance between the centers of two holes.

So what does this "tolerance" expression mean . . .?

Think of the first number, 23.35, as the ideal number, the best number possible for that dimension of your object. This number represents your goal as you fabricate/weld/cut your piece.

The next symbol, "±," means "plus or minus" -- just what it looks like top-to-bottom. The last part, the second number, is the amount your actual measured dimension can differ from the first number, how far it can be from your ideal or goal dimension. So, . . . our expression reads: "23.35 plus or minus 2 thousandths (.002) of an inch."

Notice that in this tolerance our desired measurement can be either a little bit more than the ideal or a little bit less than the ideal. This is called a bilateral, or two-sided, tolerance. A tolerance that only has tolerance on one side, either plus or minus, is a unilateral tolerance. We find unilateral tolerances with such dimensions as screw holes, where the ideal is as close as possible to the screw size, but any tighter is impossible for the screw. Most tolerances, however, are bilateral and look like the ones shown on this page.

Once we are given a tolerance, we can calculate the **range** of possible measurements that dimension can take, ranging from the **smallest or minimum size** to the **largest or maximum size** possible. To get the minimum of the range, all you have to do is subtract the second number from the first or ideal measurement. To get the maximum, you just add the second number to the first. The ideal should generally be right in the center of a bilateral tolerance.

Minimum (-)	Maximum (+)
23.35 - .002	23.35 + .002
23.350	23.350
- .002	+ .002
23.348 inches	**23.352 inches**

The acceptable range in this example is 23.348 to 23.352. This means that the distance between centers can be as small as 23.348 inches up to 23.352 inches.

*Often, on blueprints, the tolerance will be printed in the title block as a global tolerance such as "± .005" to be applied to all dimensions unless otherwise noted.

Now, knowing how tolerances work, we can use our decimal know-how to determine if a given measurement is "within tolerance."

Suppose that I had five pieces like the one shown at the beginning of this section. The following are the five measurements taken from these pieces of the distance center-to-center between the two holes. Which of the following are ***within*** tolerance and therefore good?
Which are ***outside*** the tolerance range and therefore unacceptable?

1. 23.36 ______________
2. 23.342 ______________
3. 23.349 ______________
4. 23.348 ______________
5. 23.34 ______________

Use your understanding of tolerances and comparing decimals to complete the table below. Remember to subtract to get the minimum and add to get the maximum. Look at the given measurement in the fourth column and determine if a piece dimension of that size would fall within the range of tolerance you've calculated. If it does not fall within tolerance, then write whether it is ***too small*** or ***too large***.

Tolerance	**Minimum**	**Maximum**	**Given measurement**	***Yes/No*** **Is this measurement w/in tolerance?**
3.450 ± .0005			3.453	
12.000 ± .003			12.098	
39.055 ± .0002			39.0551	
0.5 ± .001			0.49	
22 ± .01			21.095	
18.875 ± .005			18.880	

Final Grading Rubric for practical exam
Class Name: WLD 131

Name: ______________________________ Date: ______________________

Hold Points are mandatory points in the fabrication process, which require the inspector to check your work. You are required to follow the hold points.

Points Possible	***Hold Points***	***Instructor's Evaluation***
5 points	**Blueprint Interpretation and Material Cut List** 5 points = 0 errors, all parts labeled and sized correctly 3 points = 1 error in part sizing and/or identification 2 points = 2 errors 1 point = 3 errors 0 points = 4 or more errors	
10 points	**Material Layout and Cutting (Tolerances +/- 1/16")** 10 points Layout and cutting to +/-1/16" Smoothness of cut edge to 1/32" 7 points Layout and cutting to +/- 1/8" Smoothness of cut edge to 1/16 **REWORK REQUIRED IF OUT OF TOLERANCE BY MORE THAN 1/8 INCH**	
10 points	**Fit-up and Tack weld (Tolerances +/- 1/16")** 10 points Tolerances +/- 1/16" Straight and square to +/-1/16" 7 Points Tolerances +/- 1/8" Straight and square to +/-1/8" **REWORK REQUIRED IF OUT OF TOLERANCE BY MORE THAN 1/8 INCH**	
15 points	**Weld Quality** Subtract 1 point for each weld discontinuity, incorrect weld size and incorrect spacing sequence.	
28 points	***Minimum points acceptable. This equates to the minimum AWS D1.1 Code requirements.***	
	Total Points	**/40**

WLD 131 GMAW: Project Assessment Form

Student Name:_________________ Date_________

Bead Plate	Assessment	Instructor Signature/Date
Flat Position		

T - Joint	Assessment	Instructor Signature/Date
Flat Position 1F		
Horizontal Position 2F		
Vertical Up 3F		
Vertical Down 3F		
Overhead 4F		

Lap Joint	Assessment	Instructor Signature/Date
Flat position 1F		
Horizontal 2F		
Vertical 3F		
Overhead 4F		

Butt Joint	Assessment	Instructor Signature/Date
Flat Position 1F		
Horizontal 2F		
Vertical 3F		
Overhead 4F		

Horizontal Spray	Assessment	Instructor Signature/Date
T-Joint		
Butt Joint/Groove Weld		