Innershield Wire

FCAW-S Welding Guide

LINCOLN ELECTRIC

FCAW-S WELDING GUIDE

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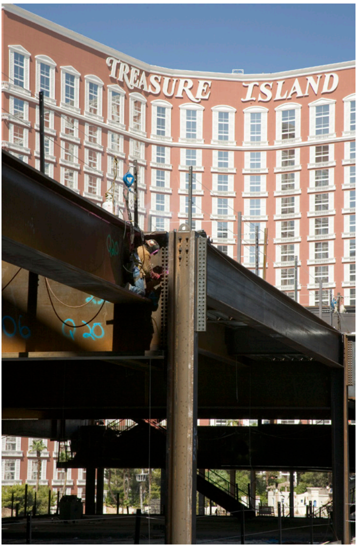

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TEST RESULTS DISCLAIMER

Test Results for Mechanical Properties, Deposit or Electrode Composition and Diffusable Hydrogen levels were obtained at a single point in time under laboratory conditions from random samples of representative material. Your results may vary within AWS specification limits depending on a variety of conditions.

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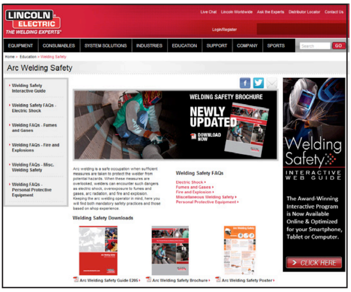
INFORMATION ON WEBSITE

Important information on the Lincoln Electric website, including:
- Link to AWS for download of ANSI Z49.1 "Safety in Welding, Cutting and Allied Processes"
- Lincoln Electric's "Arc Welding Safety" document (E205)
- "Welding Safety" interactive video. Also viewable on iPads®, smartphones and as a DVD (MC10-92)
- "Your Trusted Partner for Welding Safety Solutions" document (MC11-45)
- Material Safety Data Sheets (MSDS)
- AWS Consumable "Certificates of Conformance"
- and more!



http://www.lincolnelectric.com/en-us/education-center/welding-safety/Pages/welding-safety.aspx

SAFETY – WARNING

CALIFORNIA PROPOSITION 65 WARNINGS

For Diesel Engines

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

For Gasoline Engines

The engine exhaust from this product contains chemicals known to the State of California to cause cancer, birth defects, or other reproductive harm.

ARC WELDING CAN BE HAZARDOUS. PROTECT YOURSELF AND OTHERS FROM POSSIBLE SERIOUS INJURY OR DEATH. KEEP CHILDREN AWAY. PACEMAKER WEARERS SHOULD CONSULT WITH THEIR DOCTOR BEFORE OPERATING.

Read and understand the following safety highlights. For additional safety information, it is strongly recommended that you obtain a copy of ANSI Standard Z49.1:2012 "Safety in Welding, Cutting and Allied Processes" from The American Welding Society, 8669 NW 36 St., #130, Miami, FL 33166-6672 PH: 800-443-9353 Web: www.aws.org or CSA Standard W117.2-12 from Canadian Centre for Occupational Health and Safety, Web: www.ccohs.ca. A free copy of E205 "ArcWelding Safety" and other safety materials are available from The Lincoln Electric Co., 22801 St. Clair Ave., Cleveland, OH 44117-1199.

BE SURE THAT ALL INSTALLATION, OPERATION, MAINTENANCE AND REPAIR PROCEDURES ARE PERFORMED ONLY BY QUALIFIED INDIVIDUALS.

Mar '95

SAFETY – WARNING

FOR ENGINE Powered Equipment

1.a. Turn the engine off before troubleshooting and maintenance work unless the maintenance work requires it to be running.

1.b. Operate engines in open, well-ventilated areas or vent the engine exhaust fumes outdoors.

1.c. Do not add the fuel near an open flame welding arc or when the engine is running. Stop the engine and allow it to cool before refueling to prevent spilled fuel from vaporizing on contact with hot engine parts and igniting. Do not spill fuel when filling tank. If fuel is spilled, wipe it up and do not start engine until fumes have been eliminated.

1.d. Keep all equipment safety guards, covers and devices in position and in good repair. Keep hands, hair, clothing and tools away from V-belts, gears, fans and all other moving parts when starting, operating or repairing equipment.

1.e. In some cases it may be necessary to remove safety guards to perform required maintenance. Remove guards only when necessary and replace them when the maintenance requiring their removal is complete. Always use the greatest care when working near moving parts.

1.f. Do not put your hands near the engine fan. Do not attempt to override the governor or idler by pushing on the throttle control rods while the engine is running.

1.g. To prevent accidentally starting gasoline engines while turning the engine or welding generator during maintenance work, disconnect the spark plug wires, distributor cap or magneto wire as appropriate.

1.h. To avoid scalding, do not remove the radiator.

ELECTRO-MAGNETIC FIELDS May Be Dangerous

2.a. Electric current flowing through any conductor causes localized electro-magnetic fields (EMF). Welding current creates EMF around welding cables and welding machines.

2.b. EMF may interfere with some pacemakers, and welders having a pacemaker should consult their physician before welding.

2.c. Exposure to EMF in welding may have other health effects which are now not known.

2.d. All welders should use the following procedures in order to minimize exposure to EMF from the welding circuit:

2.d.1. Route the electrode and work cables together – Secure them with tape when possible.

2.d.2. Never coil the electrode lead around your body.

ELECTRO-MAGNETIC FIELDS May Be Dangerous (Cont'd)

2.d.3. Do not place your body between the electrode and work cables. If the electrode cable is on your right side, the work cable should also be on your right side.

2.d.4. Connect the work cable to the work piece as close as possible to the area being welded.

2.d.5. Do not work next to welding power source.

ELECTRIC SHOCK Can Kill

3.a. The electrode and work (or ground) circuits are electrically "hot" when the welder is on. Do not touch these "hot" parts with your bare skin or wet clothing. Wear dry, hole-free gloves to insulate hands.

3.b. Insulate yourself from work and ground using dry insulation. Make certain the insulation is large enough to cover your full area of physical contact with work and ground.

In addition to the normal safety precautions, if welding must be performed under electrically hazardous conditions (in damp locations or while wearing wet clothing; on metal structures such as floors, gratings or scaffolds; when in cramped positions such as sitting, kneeling or lying, if there is a high risk of unavoidable or accidental contact with the work piece), use the following equipment:

- **Semiautomatic DC Constant Voltage (aka Wire) Welder**
- **DC Manual Constant Current (aka Stick) Welder**
- **AC Constant Current Welder with Reduced Voltage Control**

3.c. In semiautomatic or automatic wire welding, the electrode, electrode reel, welding head, nozzle or semiautomatic welding gun are also electrically "hot".

3.d. Always be sure the work cable makes a good electrical connection with the metal being welded. The connection should be as close as possible to the area being welded.

3.e. Ground the metal to be welded to a good electrical (earth) ground.

3.f. Maintain the electrode holder, work clamp, welding cable and welding machine in good, safe operating condition. Replace damaged insulation.

3.g. Never dip the electrode in water for cooling.

3.h. Never simultaneously touch electrically "hot" parts of electrode holders connected to two welders because voltage between the two can be the total of the open circuit voltage of both welders.

3.i. When working above floor level, use a safety belt to protect yourself from a fall should you get a shock.

3.j. Also see Items 6.c. and 8.

SAFETY – WARNING

ARC RAYS Can Burn

4.a. Use a shield with the proper filter and cover plates to protect your eyes from sparks and the rays of the arc when welding or observing open arc welding. Head shield and filter lens should conform to ANSI (American National Standards Institute) Z87.I standards. Website: www.ansi.org.

4.b. Use suitable clothing made from durable flame-resistant material to protect your skin and that of your helpers from the arc rays.

4.c. Protect other nearby personnel with suitable, non-flammable screening and/or warn them not to watch the arc nor expose themselves to the arc rays or to hot spatter or metal.

FUMES AND GASES Can Be Dangerous

5.a. Welding may produce fumes and gases hazardous to health. Avoid breathing these fumes and gases. When welding, keep your head out of the fume. Use enough ventilation and/or exhaust at the arc to keep fumes and gases away from the breathing zone. When welding with electrodes which require special ventilation such as stainless or hard facing (see instructions on container or MSDS) or on lead or cadmium plated steel and other metals or coatings which produce highly toxic fumes, keep exposure as low as possible and below Threshold Limit Values (TLV) using local exhaust or mechanical ventilation. In confined spaces or in some circumstances, outdoors, a respirator may be required. Additional precautions are also required when welding on galvanized steel.

5.b. Do not weld in locations near chlorinated hydrocarbon vapors coming from degreasing, cleaning or spraying operations. The heat and rays of the arc can react with solvent vapors to form phosgene, a highly toxic gas, and other irritating products.

5.c. Shielding gases used for arc welding can displace air and cause injury or death. Always use enough ventilation, especially in confined areas, to insure breathing air is safe.

5.d. Read and understand the manufacturer's instructions for this equipment and the consumables to be used, including the material safety data sheet (MSDS) and follow your employer's safety practices. MSDS forms are available from your welding distributor or from the manufacturer.

5.e. Also see item 1.b.

SAFETY – WARNING

WELDING SPARKS Can Cause Fire or Explosion

6.a. Remove fire hazards from the welding area. If this is not possible, cover them to prevent the welding sparks from starting a fire. Remember that welding sparks and hot materials from welding can easily go through small cracks and openings to adjacent areas. Avoid welding near hydraulic lines. Have a fire extinguisher readily available.

6.b. Where compressed gases are to be used at the job site, special precautions should be used to prevent hazardous situations. Refer to “Safety in Welding and Cutting” (ANSI Standard Z49.1) and the operating information for the equipment being used.

6.c. When not welding, make certain no part of the electrode circuit is touching the work or ground. Accidental contact can cause overheating and create a fire hazard.

6.d. Do not heat, cut or weld tanks, drums or containers until the proper steps have been taken to insure that such procedures will not cause flammable or toxic vapors from substances inside. They can cause an explosion even though they have been “cleaned”. For information, purchase “Recommended Safe Practices for the Preparation for Welding and Cutting of Containers and Piping That Have Held Hazardous Substances”, AWS F4.1 from the American Welding Society (see address above).

6.e. Vent hollow castings or containers before heating, cutting or welding. They may explode.

6.f. Sparks and spatter are thrown from the welding arc. Wear oil free protective garments such as leather gloves, heavy shirt, cuff less trousers, high shoes and a cap over your hair. Wear ear plugs when welding out-of-position or in confined places. Always wear safety glasses with side shields when in a welding area.

6.g. Connect the work cable to the work as close to the welding area as practical. Work cables connected to the building framework or other locations away from the welding area increase the possibility of the welding current passing through lifting chains, crane cables or other alternate circuits. This can create fire hazards or overheat lifting chains or cables until they fail.

6.h. Also see item 1.c.

FOR ELECTRICALLY Powered Equipment

7.a. Turn off input power using the disconnect switch at the fuse box/circuit breaker box before working on the equipment.

7.b. Install equipment in accordance with the U.S. National Electrical Code, all local codes and the manufacturer’s recommendations.

7.c. Ground the equipment in accordance with the U.S. National Electrical Code and the manufacturer’s recommendations.

PRÉCAUTIONS DE SÛRETÉ

Pour votre propre protection lire et observer toutes les instructions et les précautions de sûreté specifiques qui parraissent dans ce manuel aussi bien que les précautions de sûreté générales suivantes:

Sûreté Pour Soudage A L'Arc

1. Protegez-vous contre la secousse électrique:
   a. Les circuits à l'électrode et à la piéce sont sous tension quand la machine à souder est en marche. Eviter toujours tout contact entre les parties sous tension et la peau nue ou les vétements mouillés. Porter des gants secs et sans trous pour isoler les mains.

   b. Faire trés attention de bien s'isoler de la masse quand on soude dans des endroits humides, ou sur un plancher metallique ou des grilles metalliques, principalement dans les positions assis ou couché pour lesquelles une grande partie du corps peut être en contact avec la masse.

   c. Maintenir le porte-électrode, la pince de masse, le câble de soudage et la machine à souder en bon et sûr état defonctionnement.

   d. Ne jamais plonger le porte-électrode dans l'eau pour le refroidir.

   e. Ne jamais toucher simultanément les parties sous tension des porte-électrodes connectés à deux machines à souder parce que la tension entre les deux pinces peut être le total de la tension à vide des deux machines.

   f. Si on utilise la machine à souder comme une source de courant pour soudage semi-automatique, ces precautions pour le porte-électrode s'applicuent aussi au pistolet de soudage.

2. Dans le cas de travail au dessus du niveau du sol, se protéger contre les chutes dans le cas ou on recoit un choc. Ne jamais enrouler le câble-électrode autour de n'importe quelle partie du corps.

3. Un coup d'arc peut être plus sévère qu'un coup de soliel, donc:
   a. Utiliser un bon masque avec un verre filtrant approprié ainsi qu'un verre blanc afin de se protéger les yeux du rayonnement de l'arc et des projections quand on soude ou quand on regarde l'arc.

   b. Porter des vêtements convenables afin de protéger la peau de soudeur et des aides contre le rayonnement de l'arc.

   c. Protéger l'autre personnel travaillant à proximité au soudage à l'aide d'écrans appropriés et non-inflammables.

PRÉCAUTIONS DE SÛRETÉ

4. Des gouttes de laitier en fusion sont émises de l'arc de soudage. Se protéger avec des vêtements de protection libres de l'huile, tels que les gants en cuir, chemise épaisse, pantaloons sans revers, et chaussures montantes.

5. Toujours porter des lunettes de sécurité dans la zone de soudage. Utiliser des lunettes avec écrans lateraux dans les zones où l'on pique le laitier.

6. Eloigner les matériaux inflammables ou les recouvrir afin de prévenir tout risque d'incendie dû aux étincelles.

7. Quand on ne soude ne pas, poser la pince à un endroit isolé de la masse. Un court-circuit accidental peut provoquer un échauffement et un risque d'incendie.

8. S'assurer que la masse est connecté le plus prés possible de la zone de travail qu'il est pratique de le faire. Si on place la masse sur la charpente de la construction ou d'autres endroits éloignés de la zone de travail, on augmente le risqué de voir passer le courant de soudage par les chaines de levage, câbles de grue, ou autres circuits. Cela peut provoquer des risques d'incendie ou d'echauffement des chaines et des câbles jusqu'à ce qu'ils se rompent.

9. Assurer une ventilation suffisante dans la zone de soudage. Ceci est particuliérement important pour le soudage de tôles galvanisées plombées, ou cadmiées ou tout autre métal qui produit des fumeés toxiques.

10. Ne pas souder en présence de vapeurs de chlore provenant d'opérations de dégraissage, nettoyage ou pistolage. La chaleur ou les rayons de l'arc peuvent réagir avec les vapeurs du solvant pour produire du phosgéne (gas fortement toxique) ou autres produits irritants.

11. Pour obtenir de plus amples renseignements sur la sûreté, voir le code "Code for safety in welding and cutting" CSA Standard W 117.2-1974.

PRÉCAUTIONS DE SÛRETÉ POUR LES MACHINES À SOUDER À TRANSFORMATEUR ET À REDRESSEUR

1. Relier à la terre le chassis du poste conformement au code de l'électricité et aux recommendations du fabricant. Le dispositif de montage ou la piece à souder doit être branché à une bonne mise à la terre.

2. Autant que possible, I'installation et l'entretien du poste seront effectués par un électricien qualifié.

3. Avant de faires des travaux à l'interieur de poste, la debrancher à l'interrupteur à la boite de fusibles.

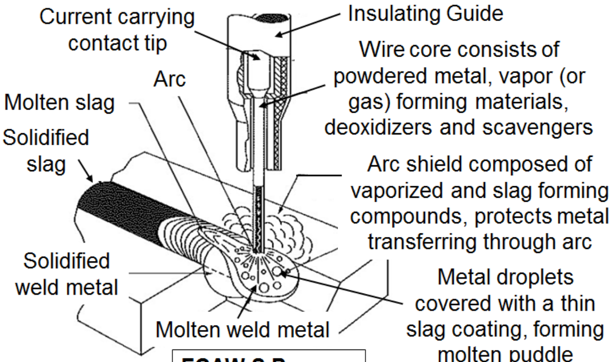
4. Garder tous les couvercles et dispositifs de sûreté à leur place.

INTRODUCTION

Protection From The Atmosphere

A fundamental principle of arc welding is that the arc and molten weld metal must be protected from exposure to the atmosphere. Otherwise nitrogen and oxygen (approximately 99% of air's constituents) will react with the arc and will be absorbed into the molten metal. Before the puddle solidifies, the absorbed gases may not completely escape. The result is porosity in the weld metal and typically a significant decrease in the weld's mechanical properties (particularly CVNs).

To achieve protection from the atmosphere, arc welding processes use either a slag system and/or an external shielding gas system. With a slag system, elements inside the electrode react with air, produce their own shielding gas and form a protective slag on the surface of the weld. While arc characteristics may be slightly less desirable (more spatter, harsher arc, etc.), these processes are very resistant to interference with the arc from surrounding air flow (wind, fans, etc.). On the other hand, external shielding gas systems deliver a particular gas or gas mix out from the end of the welding gun, where it surrounds the arc and weld pool, displacing the air and acting as a protective barrier for a second or two until the puddle solidifies. This gas environment generally improves the arc characteristics and resulting operator appeal (less spatter, smoother arc, etc.). However, these processes are very sensitive to arc interference and contamination from surrounding air flow.



FCAW-S Process

INTRODUCTION

FCAW-S Process

The Flux-Cored Arc Welding (FCAW) process is one that uses a continuously fed electrode to supply filler metal to the arc. The electrode is not solid, but rather is tubular with flux inside of it. This process is then divided into two fundamentally different sub-processes; the Self-Shielded Flux-Cored Arc Welding (FCAW-S) process and the Gas-Shielded Flux-Cored Arc Welding (FCAW-G) process. While electrodes for both sub processes produce a slag covering over the weld, the method in which they protect the arc from the surrounding atmosphere is quite different. With the FCAW-S process, reactionary agents necessary to shield the arc and cleanse the molten weld pool are placed inside the tube. No additional shielding is required (see drawing on page 11). Whereas the FCAW-G process has a different type of flux core system and relies completely on an external shielding gas for atmospheric protection. This guide only covers FCAW-S electrodes.

The FCAW-S process is unique compared to the other main arc welding processes in that it actually relies on the arc being exposed to the atmosphere and the resulting reactions with the core elements which then cleanse the weld pool and help create the protective slag. To do this, the FCAW-S process predominantly uses an aluminum-magnesium deoxidizing and de-nitriding cleansing system (vs. a primarily silicon-manganese system used by the other main arc welding processes, including FCAW-G). The weld metal is typically composed of an average of 1% aluminum, much more than is present in the weld metal from the other welding processes. However, it should be noted that it is not in a pure state, but rather in the form of beneficial compounds. The aluminum and magnesium atoms enter the weld pool where they attract oxygen and nitrogen atoms and form compounds of aluminum oxide, aluminum nitride and magnesium oxide. These compounds, particularly magnesium oxide, have high melting temperatures. This means that as the molten weld pool starts to cool, they solidify more rapidly than other elements in the pool (i.e. are “fast freezing”). These lightweight, fast freezing compounds float to the weld surface quickly and protect the process from further atmospheric contamination. Thus the slag system in effect transforms oxygen and nitrogen, two potential contaminants, into chemical compounds that protect the weld.

INTRODUCTION

Innershield Electrodes

The Lincoln Electric Company invented the first self-shielded flux-cored electrode in 1958, which developed into the Innershield line of electrodes (aka Innershield wires). They are often described as a “stick electrode turned inside out” and are frequently used in place of the Shielded Metal Arc Welding (SMAW) or stick welding process. Innershield is an important process for steel fabrication in many industries, particularly when done outdoors. For example, it is a primary welding process for structural steel building erection. In any shop, ship yard, offshore yard or cross country pipe line where wind is problematic with gas shielded processes (i.e. blowing critical shielding gas from the arc leaving the puddle unprotected), Innershield can be a great solution. Ask Lincoln Electric, the Innershield experts, to show you how.

Innershield Features

- No external shielding gas required.
- Good mechanical properties.
- Some electrodes capable of all position welding.
- Can be used in wind speeds of up to 30 mph without losing mechanical properties and favorable operating characteristics.
- Electrodes are very stiff with high column strength, providing excellent feedability.
- More tolerant of plate contaminants and off-analysis steels.

Innershield Advantages Over Stick Welding Process

- Innershield is a continuous process. This means less starts and stops, reducing the amount of potential weld discontinuities, saving money and increasing quality.
- This also increases productivity, allowing the welder to spend more time welding, not changing rods, decreasing labor costs. Arc time and operating factor are higher.
- Innershield has higher deposition rates, allowing welds of equal size to be made faster.
- Innershield does not produce “stubs” like the stick process. This increases the electrode efficiency or increases the amount of purchased electrode that ends up as deposited weld metal.

Innershield Advantages Over Gas-Shielded Welding Processes

- Innershield does not require an external gas shielding.
- No external shielding eliminates shielding gas cost, cylinder rental cost and cylinder handling, saving time and money.
- No shielding gas means simpler guns and feeders for lower maintenance costs.
- No shielding gas means there is no requirement for tenting to keep wind away from the weld joint, thus saving labor costs.
- Innershield electrodes are stiff, resulting in excellent feedability.
- All flux-cored wires naturally form a ball of slag on the end of the electrode after each weld. This ball acts as an insulator and thus must be removed for proper arc striking of the next weld. Stiff wire allows the welder to break off the end by hand, without the time consuming need of wire clippers.
- Innershield handles surface contaminants on steel (rust, mill scale, coatings, etc.) better than solid wires. Additional deoxidizing and scavenging elements are added to the core ingredients, in addition to what is present in the steel sheath.

Innershield Limitations Compared To Gas-Shielded Welding Processes

- Most Innershield electrodes generally have lower operator appeal compared to gas shielded processes (i.e. harsher arc, more spatter, higher fume generation levels).
- In some cases, a higher level of operator skill is required.
- Electrode efficiency is less (83% vs. 86% to 97%).
- Innershield electrodes produce light to heavy slag. Gas-shielded flux-cored electrodes all have a light slag, while solid and metal- core electrodes leave no slag, requiring no post weld cleaning.

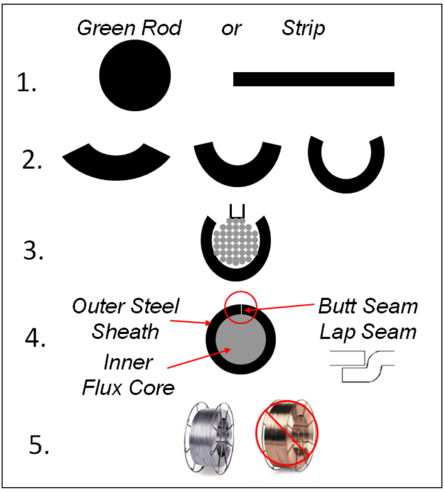
INTRODUCTION

Manufacturing Innershield Electrodes

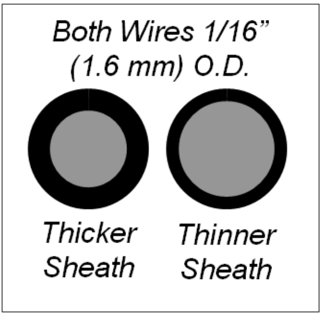
The process of drawing down and adding flux to the inside of an electrode is much more complex than drawing down solid electrodes (i.e. MIG wire). Flux-cored electrodes are considered “fabricated” wires. The basic manufacturing steps include:

1. Flux-cored electrodes start off in one of two forms of raw steel, round “green rod” or flat “strip”. Using green rod to make some of the Innershield electrodes is unique to Lincoln Electric.
2. The steel is drawn down and rolled into a “U” shape.
3. Flux ingredients are then uniformly poured into the U shaped tube. Monitoring equipment ensures that 100% of the electrode has the proper fill rate.
4. The electrode is then rolled together with a tight seam, which is either a butt or lap seam. The outer steel tube is called the “sheath” or “jacket” and the inner portion is the “flux core”.
5. The electrode is then drawn down to its final diameter and a lubricant is applied to the surface. This lubricant aids in wire feeding and acts as a rust inhibitor. Cored electrodes are not copper coated[(1)] like solid electrodes (i.e. TIG, MIG or submerged arc electrodes), in which the copper is attached via an acid bath and chemical reaction. If it were attempted with cored electrodes, the acid solution would seep through the seam and contaminate the flux.

[(1)] The exception is seamless flux-cored electrodes, which do have an external copper coating. This is a relatively new manufacturing process with few products in the welding market.



Sheath Thickness Variations



The ratio of the weight of the flux ingredients or "fill" compared to the total weight of the electrode is called the percent fill, which varies slightly between cored wires, depending on their density and amount of alloying elements in the core. As the outside diameter of all cored wires of a particular size designation are the same [i.e. 1/16 in. (1.6 mm), etc.], then the sheath thickness must vary, depending on percent fill. Carbon or mild steel wires generally have lower percent filler and therefore a thicker sheath. While higher alloy wires generally have a higher percent fill and therefore a thinner sheath. Hardfacing wires particularly have thinner sheaths. Sheath thickness effects a cored wire's welding characteristics, as summarized in the table below. As sheath thickness can also vary slightly from cored wire manufacturer to manufacturer, it is not uncommon for different brands of cored wires of equivalent types and sizes to weld at slightly different procedures.

Sheath Thickness	Feedability	Weld Penetration	Electrode Efficiency	Current Density	Current at Equal WFSs
Thicker	Stiffer/Easier	More	Higher	Lower	Lower
Thinner	Softer/Harder	Less	Lower	Higher	Higher

INTRODUCTION

Innershield Product Line

Lincoln Electric manufactures a complete portfolio of Innershield electrodes used for a variety of welding applications (see table).

Electrode Name	Electrode Type and Welding Position	Key Attributes/Common Applications
High Speed, Single Pass Only (no specified CVN toughness)		
Innershield NR®-5	Carbon Steel Flat and Horizontal	Single pass, up to 3/16 in. (4.8 mm) sheet metal, robotics/hard automation, automotive, propane cylinders, very fast travel speeds, 3 o'clock weld position, open root joints with copper back-up bar.
Innershield NR-131	Carbon Steel Flat and Horizontal	Single pass on 12 gauge (0.11 in. or 2.8 mm) or thicker steel, automotive, transportation, very fast travel speeds, automatic or semiautomatic welding, joining dissimilar thickness plates.
Innershield NR-152	Carbon Steel All Position (except vertical up)	Single pass, up to 3/16 in. (4.8 mm) sheet metal, designed for high speed welding on galvanized or zinc coated carbon steel, automotive, transportation, robotic and hard automation welding.
Sheet Metal to Thinner Plate/General Purpose (no specified CVNs)		
Innershield NR-211-MP	Carbon Steel All Position [except 3/32 in. (2.4 mm) diameter]	General fabrication with sheet metal, excellent operator appeal, galvanized or zinc coated sheet metal. Maximum plate thickness restrictions: - 5/16 in. (7.9 mm) for 0.030 - 0.045 dia. - 1/2 in. (12.7 mm) for 0.068 - 3/32 dia.
Innershield NR-212	Low Alloy Steel All Position	General fabrication with sheet metal to thinner plate, very good operator appeal, galvanized or zinc coated thinner plate, truck bodies, tanks, hoppers, racks and scaffolding. Maximum plate thickness restrictions: - 3/4 in. (19 mm) for all diameters
High Deposition/General Purpose (no specified CVN toughness)		
Innershield NS-3M	Carbon Steel Flat and Horizontal	Very high deposition rates, large groove and fillet welds, machinery bases, heavy equipment repair, installing wear plates, increased resistance to hydrogen cracking and porosity, good on high sulfur and off-analysis steels, low penetration/minimal admixture welds.
Innershield NR-311	Carbon Steel Flat and Horizontal	Very high deposition rates, fillet and groove welds on 1/8 in. (3.2 mm) and thicker steel, general fabrication, structural, assembly welding, deep penetration, fast travel speeds, good slag removal in deep grooves.

INTRODUCTION

Electrode Name	Electrode Type and Welding Position	Key Attributes/Common Applications
All Position/Structural (with CVN toughness properties)		
Innershield NR-203MP	Carbon Steel All Position	Open root welding, handles poor fit-up and gaps up to 3/8 in. (6.4 mm) wide, general plate fabrication, galvanized plate, bridge fabrication, structural, hull plate and stiffener welding on ships and barges, etc.
Innershield NR-203 Nickel (1%)	Low Alloy All Position	Open root welding, handles poor fit-up. Produces a nickel alloyed weld deposit (just under 1%) for NACE applications or color match with weathering steels for bridges and other structural fabrication. Also for offshore and groove welds on heavy wall tubular construction.
Innershield NR-203 Ni C Plus-H	Low Alloy All Position	Open root welding, handles poor fit-up. Produces a nickel alloyed weld deposit (1.0 – 2.0%) and meets an “H8” maximum diffusible hydrogen rating. Used for offshore, weathering steel, structural, bridges, hull plate and stiffener welding on ships and barges and general fabrication.
Innershield NR-232	Carbon Steel All Position (except vertical down)	For 3/16 in. (4.8 mm) and thicker steel. Maximum deposition rates when welding out-of-position. Has a heavy, fast freezing, self peeling slag system and penetrating arc. Produces smooth, flat weld beads. Used for structural fabrication, including those subject to seismic requirements (meets AWS D1.8 seismic lot waiver requirements). Also for hull plate and stiffener welding on ships and barges, machinery parts, tanks, hoppers, racks, scaffolding and general plate fabrication.
Innershield NR-233	Carbon Steel All Position (except vertical down)	Same attributes and applications as Innershield NR-232, but with a softer arc characteristic and a slightly easier to manage slag system. NR-233 is generally preferred to NR-232 for welders new to this type of heavy slag system.
Innershield NR-440Ni2	Low Alloy All Position	Designed for offshore industry. Provides improved weldability in narrow TKY connections and poor fit up conditions. Has excellent CVN toughness (meets ABS “4YSA” and AWS “J” classifications) and meets “H8” diffusible hydrogen rating.
Innershield NR-555	Low Alloy All Position	80 ksi min. tensile strength wire for general fabrication and structural steel applications, including those subject to seismic requirements (meets AWS D1.8 seismic lot waiver requirements).

INTRODUCTION

Electrode Name	Electrode Type and Welding Position	Key Attributes/Common Applications
High Deposition/Structural (with CVN toughness properties)		
Innershield NR-305	Carbon Steel Flat and Horizontal	High deposition rates and fast travel speeds in the flat and horizontal positions. Smooth arc with lower spatter level. Used for structural fabrication, including those subject to seismic requirements (meets AWS D1.8 seismic lot waiver requirements). Also for general plate fabrication, shipyards, stiffener welding on barges, bridges and offshore applications.
Innershield NR-311 Ni	Low Alloy Flat and Horizontal	High deposition rates and fast travel speeds in the flat and horizontal positions. Used for structural fabrication, including those subject to seismic requirements (3/32 in. (2.4 mm) size meets AWS D1.8 seismic lot waiver requirements). Very good bead stacking capability with horizontal groove welds, such as column-to-column structural connections. Produces a nickel alloyed weld deposit (nominal 1.5%). Provides color match on weathering steel.
Innershield NR-FAB-70	Carbon Steel Flat and Horizontal	Best in class toughness properties and without nickel. Used for structural fabrication, including those subject to seismic requirements (meets AWS D1.8 seismic lot waiver requirements).
Cross-Country Pipelines/Vertical Down (with CVN toughness properties)		
Innershield NR-207	Low Alloy Vertical Down	Hot, fill and cap passes on API standard and artic grades X42 up to under matched X70 pipe.
Innershield NR-208-H	Low Alloy Vertical Down	Hot, fill and cap passes on up to API grade X80 pipe. Also artic grades up to under matched X70 pipe.
Pipeliner® NR-207+	Low Alloy Vertical Down	Hot, fill and cap passes on API grades X42 through X70 pipe. All "Pipeliner" products include ProTech® hermetically sealed packaging and Q2 Lot® control (certificate showing actual deposit chemistry available online).
Pipeliner NR-208-P(1)	Low Alloy Vertical Down	Hot, fill and cap passes on up to API grade X80 pipe. Best operator appeal. First choice for higher service temperatures.
Pipeliner NR-208-XP	Low Alloy Vertical Down	Hot, fill and cap passes on up to grade API X80 pipe. Excellent CVN toughness properties. First choice for lower service temperatures.

(1) Special order product.

AWS ELECTRODE CLASSIFICATIONS

Flux-cored electrodes have been classified per The American Welding Society (AWS) filler metal specifications AWS A5.20/A5.20M *Specification for Carbon Steel Electrodes for Flux-Cored Arc Welding* and AWS A5.29/A5.29M *Specification for Low Alloy Steel Electrodes for Flux-Cored Arc Welding*. These are traditional "fixed classification" systems. AWS has since introduced a new type of "open classification" system, which makes it easier to address the changing requirements of the marketplace. The first one covers all flux-cored and metal-cored electrodes. The specification is **AWS A5.36/A5.36M:2012 Specifications for Carbon and Low-Alloy Steel Flux-Cored Electrodes for Flux-Cored Arc Welding and Metal-Cored Electrodes for Gas Metal Arc Welding.** The old (A5.20/A5:20M and A5:29/A5:29M) and new (A5.36:A5.36M) specifications run concurrently with dual classification authority.

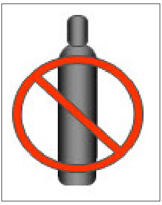
Cross reference table between old and new classification numbers.

Electrode Name	Classification per AWS A5.20 or A5.29	Classification per AWS A5.36/A5.36M:2012
High Speed, Single Pass Only (no specified CVN toughness)		
Innershield NR-5	E70T-3	E70T3S
Innershield NR-131	E70T-10	E70T10S
Innershield NR-152	E71T-14	E71T14S
Sheet Metal to Thinner Plate/General Purpose (no spec. CVNs)		
Innershield NR-211-MP	E71T-11	E71T11-AZ-CS3
Innershield NR-212	E71TG-G	E71TG-AZ-G-H16
HighDeposition/General Purpose (no specified CVN toughness)		
Innershield NS-3M	E70T-4	E70T4-AZ-CS3
Innershield NR-311	E70T-7	E70T7-AZ-CS3
All Position/Structural (with CVN toughness properties)		
Innershield NR-203MP	E71T-8J	E71T8-A4-CS3-H16
Innershield NR-203 Ni 1%	E71T8-Ni1	E71T8-A2-Ni1-H16
Innershield NR-203 Ni C Plus-H	E71T8-K2	E71T8-A2-K2
Innershield NR-232	E71T-8	E71T8-A2-CS3-H16
Innershield NR-233	E71T-8	E71T8-A2-CS3-H16
Innershield NR-440Ni2	E71T8-Ni2-JH8	E71T8-A4-Ni2-H8
Innershield NR-555	E81T8-G	E81T8-A5-K8-H8
High Deposition/Structural (with CVN toughness properties)		
Innershield NR-305	E70T-6	E70T6-A2-CS3-H16
Innershield NR-311 Ni	E70T7-K2/E80T-G-K2	E70T7-A2-K2-H16 / E80TG-A2-K2-H16
Innershield NR-FAB-70	E70T7-G	E70T7-A2-G-H16
Cross-Country Pipelines/Vertical Down (with CVN toughness properties)		
Innershield NR-207	E71T8-K6	E71T8-A2-K6-H16
Innershield NR-208-H	E91T8-G-H8	E91T8-AG-G-H8
Pipeliner NR-207+	E71T8-K6	E71T8-A2-K6
Pipeliner NR-208-XP	E81T8-G	E81T8-A4-G

SPECIAL CONSIDERATIONS

The following are special considerations when using Innershield electrodes and the FCAW-S process.

No Shielding Gas



Do **NOT** use shielding gas with FCAW-S electrodes. Granted, arc stability may improve with use of a shielding gas. However, the arc would be shielded from the atmosphere. This would not allow aluminum and magnesium from the electrode's core to react and combine with nitrogen and oxygen from the atmosphere and form compounds. The weld deposit would then end up with much higher than expected levels of primarily aluminum, resulting in very brittle, crack sensitive weld metal. Therefore, use of shielding gas with Innershield electrodes could result in weld cracking issues.

Welding Parameters

All the FCAW-S process parameters are explained in detail in the **"Welding Parameters"** section of the booklet. However, some of them deserve special consideration or an additional note of emphasis.

Welding Output Type

Only use constant voltage (CV) output with Innershield electrodes for a smooth, stable welding arc and to achieve the proper mechanical properties in the weld. Arc stability and weld properties can be unsatisfactory if used with constant current (CC) output.

Polarity

Most Innershield electrodes operate best on direct current electrode negative (DC-) or "straight" polarity. Note that this is opposite of all gas-shielded flux-cored, solid (i.e. MIG) and metal-cored electrodes, which operate best on direct current electrode positive (DC+) or "reverse" polarity. In addition, even a few of the Innershield electrodes also operate best on DC+ polarity (e.g. Innershield NS-3M, NR-305, NR-5).

Arc Voltage

Innershield electrodes tend to be more sensitive to changes in arc voltage than other processes. Depending on wire feed speed, always use the recommended corresponding arc voltage range for a particular Innershield electrode type and diameter.

Contact Tip to Work Distance (CTWD)

The normal recommended CTWD for flux-cored electrodes is 3/4 to 1 in. (20 - 25 mm). This is much longer compared to short circuit MIG welding [3/8 in. (10 mm) average]. Welding problems can occur if CTWD is too short or too long.

SPECIAL CONSIDERATIONS

Travel Angle

Always use a drag travel angle with flux-cored electrodes, trailing the slag behind the puddle. Do not use a push travel angle, as this greatly increases the chance of trapping slag and/or decreasing penetration.

Single Pass Limitations

Certain FCAW-S electrodes are limited to single pass welding only. They rely on admixture or dilution with the base metal to produce the weld deposit. If used for multiple pass welding, then after the first few passes you would begin to have an all filler metal or all weld metal deposit. The resulting alloy content of the weld bead could be undesirable and weld cracking could potentially result. These electrodes include: Innershield NR-5, NR-131, and NR-152.

Thickness Restrictions

Certain FCAW-S electrodes are limited to a maximum steel plate thickness in which they can be used. If used with plate thicknesses beyond these recommended limits, then the cooling rate of the weld metal could be faster than desired, due to the thermal conductivity or weld quenching effect of the thicker plate. This in turn could potentially create an undesirable microstructure in the weld metal, from which weld cracking issues could potentially result. Electrodes with plate thickness limitations are listed in the table directly below.

If joining plates of different thickness, ALL the plates should be within the maximum thickness restriction. The plate thickness restrictions also apply regardless if making single pass or multiple pass welds.

Wire Brand	Wire Diameter	Maximum Thickness	Weld Pass
Innershield NR-211-MP	0.030, 0.035, 0.045 in. (0.8, 0.9, 1.1 mm)	5/16 in. (7.9 mm)	Multiple
Innershield NR-211-MP	0.068, 5/64, 3/32 in. (1.7, 2.0, 2.4 mm)	1/2 in. (12.7 mm)	Multiple
Innershield NR-212	All Diameters	3/4 in. (19 mm)	Multiple
Innershield NR-5	All Diameters	3/16 in. (4.8 mm)	Single
Innershield NR-152	All Diameters	3/16 in. (4.8 mm)	Single

SPECIAL CONSIDERATIONS

Charpy V-Notch Toughness Properties

Per the appropriate carbon steel filler metal specification, note that several of the self-shielded flux-cored electrode classifications do not have a requirement for Charpy V-Notch (CVN) impact energy or toughness. Therefore, some Innershield electrodes will NOT include any notch toughness data in their product information and will NOT meet any specified minimum CVN values. These electrodes include:

- Innershield NR-5
- Innershield NR-131
- Innershield NR-152
- Innershield NR-211-MP
- Innershield NR-212
- Innershield NR-311
- Innershield NS-3M

To help illustrate this point only, the table below includes the Innershield electrode brand names and partially excerpted information from Table 1U, "A5.20 Mechanical Property Requirements" from the AWS A5.20/A5.20M:2005 carbon steel filler metal specification.

Innershield Electrode	AWS Classifi-cation	Tensile Strength (ksi)	Minimum Yield Strength (ksi)	Minimum Percent Elongation (%)	Minimum Charpy V-Notch Impact Energy
Innershield NR-5	E7XT-3	70 min.	Not Specified	Not Specified	Not Specified
Innershield NS-3M	E7XT-4	70-95	58	22	Not Specified
Innershield NR-311	E7XT-7	70-95	58	22	Not Specified
Innershield NR-131	E7XT-10	70 min.	Not Specified	Not Specified	Not Specified
Innershield NR-211-MP	E7XT-11	70-95	58	20	Not Specified
Innershield NR-152	E7XT-14	70 min.	Not Specified	Not Specified	Not Specified

Note that the "T-6" and "T-8" classified carbon steel Innershield electrodes do have a minimum Charpy V-Notch Impact Energy specification. This means that Innershield NR-203MP, NR-232, NR-233 and NR-305 will meet a minimum CVN requirement. In addition, all of the "T7" and "T8" classified low-alloy Innershield electrodes (except E7XTG-G classification) have a minimum CVN specification. This means that Innershield NR-203 Ni(1%), NR-203 Ni C Plus-H, NR-207, NR-208-XP, NR-311 Ni, NR-FAB-70, NR-440Ni2, NR-555, Pipeliner NR-207+ and Pipeliner NR-208-XP will meet a minimum CVN requirement, but Innershield NR-212 (E71TG-G) will not.

SPECIAL CONSIDERATIONS

Tack Welding

It is recommended to use the same Innershield electrode to tack weld plates together that will then be used to weld the joint. If using stick electrodes to tack, often the flux-cored electrode's slag adheres strongly where you have welded over the stick electrode tack welds. High levels of aluminum in FCAW-S electrodes react with a rutile electrode (i.e. titanium oxide) and form a thin coating on the bottom of slag that is very hard to remove. The severity of this problem varies with different types of FCAW-S electrodes. However, tack welding with stick electrodes is often the most practical method. If this is the case, then the following stick electrodes are recommended for tack welding prior to Innershield welding. Also thoroughly remove slag from tacks before welding with Innershield.

» Fleetweld 35LS (E6011). It is designed specifically as a tacking electrode for use under Innershield welds (LS = low silicon)
» Secondly, other cellulosic stick electrodes (E6010 or E6011) or low hydrogen electrodes (E7016, E7018)
» Avoid using electrodes with a rutile coating (E6013, E7014, etc.)

Intermixing In Same Joint With Other Processes

When Innershield (FCAW-S) weld deposits are intermixed in the same joint with weld deposits from other welding processes (e.g. SMAW, GTAW, GMAW, FCAW-G or SAW), particularly when the Innershield deposit is in the root pass(es), a decrease in weld metal Charpy V-Notch toughness may occur. The unique metallurgy and slagging system of the FCAW-S process is different than the slagging system of other processes. The increased presence of aluminum and nitrogen from dilution and resulting broken compounds from the Innershield deposit into the other processes' weld metal affects the CVN results. For applications requiring good notch toughness, testing of the intermixed weld metal with the specific electrodes used is recommended to ensure that it meets the minimum CVN requirement.

Aging

The AWS filler metal specifications for these Innershield products permit aging of test specimens. Aging is the process of holding test specimens at an elevated temperature for a set amount of time [e.g. 200° F to 220° F (95° C to 105° C) for 48 ± 2 hours] to allow hydrogen to migrate or diffuse out of the weld metal at a faster rate than what would naturally occur at room temperature over a longer period of time. When conducting welding procedure or operator qualification tests, it is recommended that aging be applied to test specimens before mechanical testing, whenever permitted by the appropriate code. For example, if qualifying procedures to the ***AWS D1.1/D1.1M:2010 Structural Welding Code,*** see Paragraph 4.3.2 for details.

SPECIAL CONSIDERATIONS

Arc Gouging

When arc gouging welds made with Innershield electrodes, black smudges or spots may appear on the surface of the groove. The condition is aggravated when the carbon is allowed to touch the surface. These spots are often mistakenly identified as porosity. This black residue does not indicate the presence of porosity or poor weld quality. However, if desired, it can be easily removed by wire brushing or light grinding.

Seismic Structural Welding Applications

Often structural welding occurs for and on projects in seismic regions of the United States (i.e. regions that are more prone to earthquakes). Welding consumables for demand critical connections[(1)] in a seismic application must be capable of meeting stringent requirements in a variety of categories. AWS developed the D1.8 "Seismic Supplement" to the AWS D1.1 Structural Welding Code as a standard to govern a number of these key requirements specific to demand critical welding. These requirements of welding electrodes include consumable lot control, moisture resistant packaging, electrode exposure evaluations, high and low heat input weld metal tests, and weld metal intermix testing. AWS D1.8 is the result of the earlier FEMA 353 specification and some AISC documents.

The following Innershield electrodes in the table directly below meet AWS D1.8 requirements for demand critical welds. High and low heat input tested lot certifications for three different lots of each of these products are available on the Lincoln Electric website. These electrodes are also highlighted in their literature with the "FEMA 353/ D1.8" logo.

FEDERAL EMERGENCY MANAGEMENT AGENCY FEMA 353

AWS D1.8 Structural Welding Code Seismic Supplement

[(1)] Structural designer is responsible to designate which connections are seismically demand critical connections.

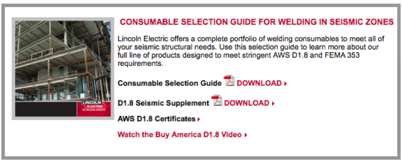
Electrode	Diameters
Innershield NR-232	0.068, 0.072, 5/64 in. (1.7, 1.8, 2.0 mm)
Innershield NR-233	1/16, 0.072, 5/64 in. (1.6, 1.8, 2.0 mm)
Innershield NR-555	1/16, 5/64 in. (1.6, 2.0 mm)
Innershield NR-305	5/64, 3/32 in. (2.0, 2.4 mm)
Innershield NR-311 Ni	3/32 in. (2.4 mm)
Innershield NR-FAB-70	3/32 in. (2.4 mm)

SPECIAL CONSIDERATIONS

Seismic Structural Welding Applications (Cont'd)

See the "D1.8 Resource Center" on the Lincoln Electric website (from home page, select "Industries" tab, then in drop down menu select "Structural") and the "D1.8 Seismic Supplement Welding Manual" (C1.65) for more information on seismic welding applications.

http://www.lincolnelectric.com/en-us/industries/structural/Pages/structural.aspx



Unintentional Inductance

Inductance is a naturally occurring phenomenon in any electrical circuit in which current is flowing, including a welding circuit. In simplest terms, inductance is resistance to a change in current flow (either increasing or decreasing current). A welding arc is dynamic, in which current and voltage are changing constantly. Therefore inductance can be beneficial in that it helps resist these current changes up or down and thus produces a more stable welding arc.

However, inductance can have unwanted effects also, particularly when it is unintentional inductance. This can occur when large external inductors are inadvertently created in the welding circuit, resulting in high, uncontrolled external inductance. This inductance can result in disturbing the welding arc and can significantly reduce the useable current output of the power source. The effect can be more noticeable with the FCAW-S process, where arc stability is decreased and/or the welding machine's output does not feel "hot enough".

SPECIAL CONSIDERATIONS

Unintentional Inductance (Cont'd)

A common source of unintentional inductance can come from long lengths of welding cable, particularly when current is flowing through them while they are still coiled up (see photo at right for example). Long lengths of cable should be unrolled and stretched out when using. Also avoid winding the welding cable directly around the power source. Additionally, when the full length of cable is not needed for a particular job, the use of male and female cable quick connect plugs can make it easy to take most of the cable completely out of the welding circuit.

Unintentional inductance can also occur in the particular case of when Innershield electrodes are being used with pure DC generator type engine driven welders with Dual Continuous Control (see figure for example). When using these types of welders with an optional Wire Feed Module and CV output, the "Course Current Switch" or "Current Range Selector Switch" should be set to the maximum tap. Then arc voltage is controlled with the "Fine Current and OCV Switch" or "Voltage Adjustment Dial". While the course current switch is not controlling the level of welding output, there is still current flowing through it and therefore it is producing a certain degree of self-inductance. The higher this self-inductance, the more arc interference you can get. This inductance is lowest when the tap is at its maximum setting. For a crisper arc characteristic, move the tap one position less than maximum. Note that this issue is only related to pure DC generator type engine drives. Chopper Technology® and Reactor Technology engine drives use different circuitry, where this issue is not present.

INNERSHIELD EQUIPMENT

Innershield electrodes are used with a variety of welding equipment. Most welding is done semiautomatically, requiring a power source, wire feeder and welding gun. Some Innershield applications are welded automatically, utilizing automatic welding equipment with special Innershield nozzles, wire straighteners, and other accessories.

Power Sources

Most Innershield electrodes are 1/16 in. (1.6 mm) diameter or larger and operate at fairly high current levels. Therefore, an industrial, three-phase power source of at least 350 amps capacity is generally required. Common power sources include Lincoln Electric's transformer/rectifier based machines (e.g. Idealarc® DC family, Idealarc CV family, etc.), inverter based machines (e.g. Invertec® family, FLEXTEC® family, etc.) or engine driven machines (e.g. Ranger® family, Vantage® family, etc.). A few Innershield electrodes are available in 0.045 in. (1.1 mm) or smaller diameters and can be used with smaller, single phase, compact wire feeder/welder units (e.g. Power MIG® family, etc.). Note all power sources for use with Innershield electrodes should have constant voltage (CV) output.

Examples of Welding Machines Used with Innershield Electrodes

Flux-cored electrodes, such as the Innershield wires, can also be used on power sources with pulse welding capability (e.g. Power Wave® family, etc.). However, the use of pulse waveforms with flux-cored electrodes has not generally proven to show any measurable benefits, as they have with solid and metal-cored electrodes. Therefore, Innershield wires are generally used with the power source's constant voltage (CV) modes and not with pulsing modes.

INNERSHIELD EQUIPMENT

Welding Cable

Welding cable is needed for both the electrode and work sides of the welding circuit. Choose the appropriate AWG cable size per the chart.

Current Output @ 60% Duty Cycle	Total Electrode and Work Cable Length			
	0-50 ft. (0-15 m)	50-100 ft. (15-30 m)	100-150 ft. (30-45 m)	150-200 ft. (45-60 m)
200 Amps	#2 (35 mm^2)	#2 (35 mm^2)	#2 (35 mm^2)	#1 (50 mm^2)
300 Amps	#1/0 (50 mm^2)	#1/0 (50 mm^2)	#1/0 (50 mm^2)	#2/0 (70 mm^2)
400 Amps	#2/0 (70 mm^2)	#2/0 (70 mm^2)	#2/0 (70 mm^2)	#3/0 (95 mm^2)
500 Amps	#2/0 (70 mm^2)	#2/0 (70 mm^2)	#3/0 (95 mm^2)	#3/0 (95 mm^2)
600 Amps	#3/0 (95 mm^2)	#3/0 (95 mm^2)	#3/0 (95 mm^2)	#4/0 (120 mm^2)

Note: mm^2 equivalent size to AWG size, according to the International Electrical Code (IEC)

Semiautomatic Wire Feeders

Since most Innershield electrodes are fairly large in diameter, this means that heavy duty, industrial, constant speed, semiautomatic wire feeders are generally required. Common wire feeders include Lincoln Electric's shop based, platform style wire feeders (e.g. LF family, LN family, Flex Feed™ family, Power Feed® family etc.) or field based, suitcase style wire feeders (e.g. LN family, Activ8™, etc.).


Cored electrodes also require the use of "knurled" drive rolls. A cored electrode cannot withstand as much drive roll tension or squeezing force as a solid electrode can with smooth drive rolls. The electrode would be crushed or deformed. The drive roll's knurls (i.e. teeth) help grip the cored electrode, providing equivalent pushing force, but with less drive roll tension.

Note: Knurled drive rolls are not recommended for solid electrodes. The knurls can potentially chew or flake off some of the electrode's external copper coating, causing liner clogging issues. However, cored electrodes with a seam do not have an external copper coating and thus do not have this potential wire feeding issue.

INNERSHIELD EQUIPMENT

Innershield Welding Guns

Lincoln Electric has a full line of welding guns designed specifically for Innershield electrodes. Opposed to MIG guns, they do not utilize the flow of shielding gas through them to help dissipate heat. They are rugged and durable, yet lightweight. The traditional gun line includes the K126™ Classic, K115, K116 and K345 guns, as well as K206 and K289-1 fume extraction guns.

The newer K126™ PRO Innershield guns are a hybrid between a traditional Innershield gun and a gas shielded MIG gun. While rugged and lightweight, they also have the advantage of a replaceable liner, changeable back end gun connector, chrome plated and braided gun tube options and same contact tips as the Magnum® PRO series MIG guns. In addition, they are more efficient because of improved internal connections. At equal wire feed speeds, welding current is an average of 10 amps higher than with the K126 Classic Innershield gun.

K126 Classic

K115

K116

K126 PRO

INNERSHIELD EQUIPMENT

Innershield Welding Guns (Cont'd)

Choose the right Innershield gun and related parts for your need.

Gun Name	Rated Amps @ 60% Duty Cycle	Length ft. (m)	Wire Diameter Range in. (mm)	Gun Tube Angle(1)	Gun Picture
Standard Guns					
K126-10 PRO	350	10 (3.0)	1/16-3/32(2) (1.6-2.4)	62°	
K126-11 PRO	350	15 (4.5)	1/16-3/32(2) (1.6-2.4)	62°	
K126-12 PRO	350	15 (4.5)	1/16-5/64(2) (1.6-2.0)	62°	
K126-13 PRO	350	15 (4.5)	1/16-3/32(2) (1.6-2.4)	30°	
K126-1 Classic	350	10 (3.0)	1/16-3/32 (1.6-2.4)	62°	
K126-2 Classic	350	15 (4.5)	1/16-3/32 (1.6-2.4)	62°	
K115-1	450	10 (3.0)	7/64-0.120 (2.8-3.0)	82°	
K115-2	450	15 (4.5)	7/64-0.120 (2.8-3.0)	82°	
K115-3	450	10 (3.0)	3/32 (2.4)	82°	
K115-4	450	15 (4.5)	3/32 (2.4)	82°	
K115-8	450	15 (4.5)	7/64-0.120 (2.8-3.0)	45°	
K115-10	450	15 (4.5)	3/32 (2.4)	45°	
K116-2	600	15 (4.5)	7/64-0.120 (2.8-3.0)	Straight	
Pipe Welding Gun: Used only with LN-23P wire feeder (has reduced WFS thumb switch)					
K345-10	350	10 (3.0)	0.068-5/64 (1.7-2.0)	90°	
Fume Extraction Guns: Used with high vacuum extraction units					
K206	350	15 (4.5)	1/16-3/32 (1.6-2.4)	62°	
K289-1	500	15 (4.5)	5/64-0.120 (2.0-3.0)	82°	

(1) Included with gun. Many guns have additional gun tube options with different angles.
(2) Gun liner and contact tip can be changed for use with 0.035 and 0.045 in. (0.9 and 1.1 mm) wire.

INNERSHIELD EQUIPMENT

Innershield Welding Guns (Cont'd)

<table>
<tr><th>Gun Name</th><th>Contact Tip</th><th>Tip Holder</th><th>Insulated/ Thread Protector</th><th>Insulator Guide</th><th>Gun Tube (Nozzle)(1)</th></tr>
<tr><td>K126 PRO</td><td>KP2745-X</td><td>KP2908-1</td><td>KP2907-1</td><td rowspan="2">KP1987-1
KP1995-1
KP2090-1</td><td>KP2906-X
KP2927-X</td></tr>
<tr><td>K126 Classic and K345</td><td rowspan="2">KP2100-X
KP2935-X</td><td>Nozzle Liner and Insert</td><td>KP2089-1</td><td>KP1914-X
KP1909-1
KP1920-1</td></tr>
<tr><td>K206</td><td rowspan="3">KP2094-X,
KP2095-X</td><td>---</td><td>KP2099-X
KP1993-1
KP1994-1</td><td>KP1909-1
KP1914-2</td></tr>
<tr><td>K115 and K116</td><td rowspan="2">KP2103-X,
KP2088-X</td><td>---</td><td>KP1971
KP1965-X</td><td>KP1907-X
KP1910-X
KP1908-X</td></tr>
<tr><td>K289</td><td>---</td><td>KP2099-X
KP1993-1
KP1994-1</td><td>KP1909-1
KP1914-2</td></tr>
</table>

(1) Gun tubes are interchangeable between the K126 PRO, K126 Classic , K115, K116 and K345 guns.

KP2745-X


KP2908-1


KP2907-1


KP2906-X


KP2927-X

Gun Tubes
A variety of gun tubes (aka nozzles or goosenecks) of various angles, lengths and jacket types (classic braided or stainless steel) are available for the Innershield guns. These gun tubes are interchangeable between the K126™ PRO(1), K126™ Classic, K115, K116 and K345 guns. The back ends all have the same 1/2 in. (12.7 mm) outside diameter.

Reverse Bend Gun Tubes
The majority of Innershield electrodes are very stiff with great column strength and feedability. They also feed out of the curved gun tube with a stiff bend, potentially prematurely wearing one side of the contact tip. Therefore, to help straighten the wire and achieve less and uniform tip wear, the gun tube has a second, "reverse bend" in it.

(1) A short liner (not supplied) must be installed in K126 PRO gun tubes when not used with PRO guns.

Innershield Welding Guns (Cont'd)

Non-Reverse Bend Gun Tubes

Some self-shielded flux-cored electrodes may have a thinner outer steel sheath and/or may be softer. This reduces their stiffness and resulting feedability. This is particularly the case with hardfacing flux-cored electrodes (i.e. "Lincore®" family). Sometimes feeding them through standard reverse bend gun tubes can be troublesome. Therefore, a series of "non-reverse bend" gun tubes are available for use with the Innershield guns if feeding problems are encountered. These gun tubes do not have the second bend in them.

Gun Name	Gun Tube Description, Curve and Length [angle/in. (mm)]	"Reverse Bend" Gun Tube Part Number	"Non-Reverse Bend" Gun Tube Part Number
Stainless Steel Jacket			
K126 PRO	62°/6 (152)	---	KP2906-62
	30°/6 (152)	---	KP2906-30
	30°/12 (305)	---	KP2906-30-L
	62°/6 (152)	KP2906-62R(2)	---
	30°/6 (152)	KP2906-30R(2)	---
	30°/12 (305)	KP2906-30R-L(2)	---
Classic Braided Varnish Jacket			
K126 PRO	30°/12 (305)	---	KP3267-1(3)
	62°/6 (152)	KP2927-62R(3)	---
	30°/12 (305)	KP2927-30R-L(3)	---
	30°/11.7 (297)	KP2482-1(3)	---
K126 Classic and K345	62°/6 (152)	---	KP2454-1
	45°/6 (152)	---	KP2455-1
	30°/12 (305)	---	KP2456-1
	30°/6 (152)	KP1914-2	---
	30°/12 (305)	KP1914-1	---
	62°/4.5 (114)	KP1909-1	---
	90°/7 (178)	KP1920-1	---
K115	45°/8 (203)	KP1910-1(4)	---
	45°/8 (203)	KP1910-2(4)	---
	45° Hardfacing/8 (203)	---	KP1952-1(4)
	82°/6 (152)	KP1907-1(4)	---
	82°/6 (152)	KP1907-2(4)	---
	82° Hardfacing/6 (152)	---	KP1953-1(4)
K116	0° Straight/5 (127)	KP1908-1, -2	---

(2) Reverse bend gun tubes require a 3/32 in. (2.4 mm) liner.
(3) Gun tubes require corresponding gun connector and liner. Maximum diameter wire is 5/64 in. (2.0 mm).
(4) For up to 0.120 in. (3.0 mm) diameter wire.
(5) For up to 3/32 in. (2.4 mm) diameter wire.

INNERSHIELD CONSUMABLES

Diameters and Packaging

Innershield electrodes come in a variety of diameter sizes, including 0.030 in. (0.8 mm), 0.035 in. (0.9 mm), 0.045 in. (1.1 mm), 0.062 or 1/16 in. (1.6 mm), 0.068 in. (1.7 mm), 0.072 in. (1.8 mm), 5/64 in. (2.0 mm), 3/32 in. (2.4 mm), 7/64 in. (2.8 mm) and 0.120 in. (3.0 mm). Many electrodes in sizes 5/64 in. (2.0 mm) and less can be used for all position welding, while other wires in sizes 5/64 in. (2.0 mm) and more are used for in position (i.e. flat and horizontal only) welding.

Innershield electrodes also come in many package sizes, from small spools and coils to bulk packaging in Speed-Feed® reels and Speed-Feed drums. Some packages are hermetically sealed in vacuum sealed foil bags or pails. The table below shows the various Innershield electrode packaging weights and sizes.

Various Innershield Electrode Packaging

Hermetically Sealed Innershield Packaging

Weight lbs. (kg)	Coils	Spools	Reels	Drums
1 (0.4)		X		
8 (3.6)		X		
10 (4.5)		X		
12.5 (5.7)		X		
13.5/14 (6.1/6.4)	X			
15 (6.5)		X		
25 (11.4)		X		
50 (22.7)	X	X		
500 (227)				X
600 (273)			X	X

Note: See Lincoln Electric product catalog (C1.10) for complete packaging specifications.

INNERSHIELD CONSUMABLES

All plastic, [except 1 lb. (0.4 kg)], fiber and metal spools have a 2 in. (51 mm) inside diameter (ID) and can be loaded directly onto a wire feeder's standard 2 in. (51 mm) outside diameter (OD) spindle.

Coils, however, must be mounted onto an adapter before loading on the spindle.

Loading 13.5 lb. (6.1 kg) and 14 lb. (6.4 kg) Coils

1. A K435 Innershield coil adapter (aka pancake adapter) is required and fits wire feeders with a 2 in. (51 mm) OD spindle. Place one side of adapter onto flat surface.

2. Unpack the coil of wire. Straighten any metal tabs that may have been bent.

3. Lay coil of wire into adapter. Remove the start end of the wire. While always maintaining tension on the wire with one hand, straighten the first six inches. Cut off the first inch. Be sure the cut end is round and burr free. Otherwise, wire may hang up while initially feeding through gun, causing a "bird nest" of tangled wire at the drive rolls. Place the other side of adapter over the coil of wire and adjust until the two sides fit tightly together. There should only be a small gap between the two halves.

4. While still maintaining tension(1) on the start end of wire, place the loaded coil adapter over the wire feeder spindle, lining it up with the spindle pin. To prevent the wire from dereeling, do not allow the coil and coil adapter to spin. Install the spindle locking collar onto the spindle to hold the coil adapter firmly in place.

5. Feed the start end of wire into the wire feeder's inlet guide and push tight against the drive rolls. Hit the cold feed button or gun trigger and feed just a few inches of wire into the drive rolls. For the LN-23P wire feeder, thread the wire through the feeding liner until about four inches of wire is exposed.

6. Feed the wire the rest of the way through the drive rolls and gun. Use the wire feeder's "cold feed" option, if so equipped. For best initial wire feeding through the gun, keep the gun as straight as possible and remove the contact tip before the wire feeds past the gun tube. Then inspect and reinstall the contact tip. Also check wire braking tension at the spindle and adjust if necessary.

(1) Caution: If tension is lost on the wire (i.e. you let go of start end), several loops of wire will quickly unravel from the coil. If this occurs, carefully take off the loose loops until you find a new starting point. While maintaining tension on wire, cut loose loops.

INNERSHIELD CONSUMABLES

Loading 50 lb. (22.7 kg) Coils

1. A K1504-1 coil adapter is required for wire feeders with a 2 in. (51 mm) OD spindle. Wire feeders with the old style 1 in. (25.4 mm) OD shaft require a L4604 wire reel assembly coil adapter.

K1504-1

L4604

2. Unscrew the front side of adapter and set aside. Lay the back side of adapter on a flat surface. Place new coil of wire onto adapter, being careful that the adapter's four spring loaded arms are not lined up on a tie wire or hiding the wire label. The wire should feed from the top or bottom of coil, depending on your wire feeder's configuration.

3. Place the front side of adapter over coil, lining up with four spring loaded arms. Screw top adapter onto bottom adapter. Tighten by hand as much as possible. Do NOT tighten more with hammer.

4. Place the loaded coil adapter over the wire feeder spindle, lining it up with the spindle pin, and put on the spindle locking collar. Cut and remove the tie wires on the coil. Maintain tension on the start end of wire before the last tie wire is cut. Straighten end of wire and feed through drive rolls and gun, as described above.

WELDING PREPARATIONS

Prepare the Work

Clean the joint by removing mill scale, rust, moisture, paint, oil and grease from the surface. As with all welding processes and applications, a clean joint is necessary to avoid porosity and to attain the travel speeds indicated in the procedures.

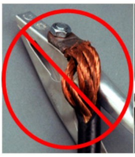
The work connection can be placed either at the beginning or at the end of the weld, depending upon the application. If necessary, try different locations until the best weld quality is obtained.

Clamp the work cable to the work so there is a positive and clean metal-to-metal contact point. Poor work connections increase the amounts of voltage drop in the welding circuit and can result in convex or ropey beads typical of low voltage, even if the machine meters indicate proper voltage.

WELDING PREPARATIONS

Prepare the Work (Cont'd)

Never use undersized or badly worn work cables.



Frayed Cable

Improper Repair and No Strain Relief for Lug Connection

Tack weld with Innershield electrode or Fleetweld 35LS, Fleetweld 5P+ or Excalibur 7018 MR. If other electrodes are used, Innershield slag removal may be difficult in the area of the tacks (see "Special Considerations" section of this booklet for more explanation).

Optimizing Feeding

Most feeding problems are caused by wrong drive roll tension or improper handling of the gun cable or electrode.

1. Loosen drive roll tension. While squeezing the wire with your gloved hand between your thumb and forefinger, cold inch the wire and push against it at the contact tip, making the drive rolls slip. Adjust the drive roll tension such that there is just enough feeding force that you can no longer stop the wire from feeding.

2. Do not kink, coil up or pull the gun cable around sharp corners. Keep the gun cable as straight as possible when welding.

3. Do not allow two-wheeled hand trucks, fork lift trucks, etc. to run over the gun cable or other damage to occur to the gun cable.

4. Keep the gun cable clean per instructions in the wire feeder operating manual.

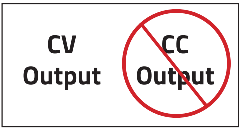
5. Innershield electrodes have proper surface lubrication on them. Do not add lubricant to wire's surface. Use only clean, rust-free electrodes.

6. Replace the gun's contact tip when it becomes worn or the end appears fused or deformed.

WARNING: When inching, the wire is always electrically "hot" to ground, except when using the "cold inch" feature on wire feeders equipped with this option.

WELDING PARAMETERS

Output Type



Only use constant voltage (CV) power sources with Innershield electrodes, because a stable arc length is critical. CV machines, with constant speed wire feeders, produce a very consistent arc length. This produces a stable, well balanced arc. With constant current (CC) (i.e. variable voltage) output, the arc length varies too much. An erratic arc results (particularly at procedures of 22 volts or less), and potentially reduced Charpy V-notch toughness properties and weld porosity.

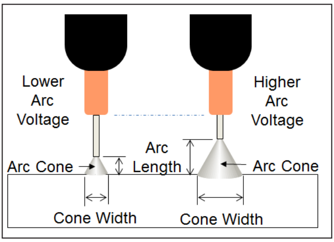
DC-

Polarity

The specific core elements or arc stabilizers used in a particular Innershield electrode determine the welding polarity in which the arc is the most stable. Most Innershield electrodes operate best on direct current electrode negative (DC-) or “straight” polarity. This is opposite of all gas-shielded flux-cored, solid (i.e. MIG) and metal-cored electrodes, which operate best on direct current electrode positive (DC+) or “reverse” polarity. Note that a few Innershield electrodes also operate best on DC+ polarity (e.g. Innershield NS-3M, Innershield NR-5 and Innershield NR-305).

Arc Voltage

Innershield electrodes tend to be more sensitive to changes in arc voltage than other processes. Voltage, measured in volts (V), affects the length of the arc. As voltage decreases, arc length gets shorter and the resulting arc cone narrower and smaller. An excessively convex or ropey bead indicates that voltage is too low. As voltage increases, arc length gets longer and resulting arc cone gets wider and larger. As arc voltage becomes excessive, the surface area of the arc cone, and the arc’s exposure to air, gets exponentially larger. There are only so many core elements inside the tubular electrode in which to react with the air and protect the weld. If the exposure level becomes too much for the core elements to handle, then additional nitrogen is absorbed into the weld metal. Reduced Charpy V-Notch toughness properties and internal and/or external porosity can result. Therefore, too much voltage on CV (or CC, where voltage is constantly fluctuating, often to excessive levels), can cause reduced CVN values and/or weld porosity.



WELDING PARAMETERS

Arc Voltage (Cont'd)

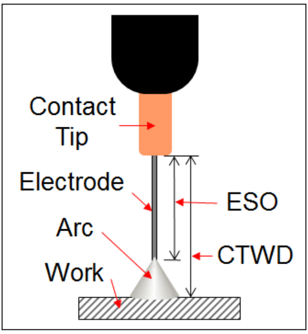
On multiple pass welds, absorption of excessive nitrogen into the weld metal from too high of voltage can be cumulative. The first few weld passes may appear sound. But then suddenly porosity is encountered in the last few fill or cap passes. This could be due to an accumulating build-up of nitrogen in the weld which finally produces visible porosity.

Use the power source's or wire feeder's voltmeter or a hand held voltmeter to set the arc voltage. **Note:** Very long cable lengths, poor work cable connections, undersized or damaged cables, and poor cable clamps can cause a significant drop between the set voltage at the power source and the actual voltage at the arc.

Contact Tip To Work Distance

WARNING: When inching, the wire is always electrically "hot" to ground, except when using the "cold inch" feature on wire feeders equipped with this option.

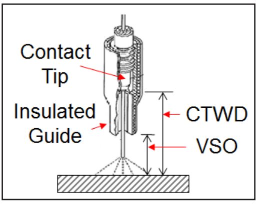
Contact tip to work distance (CTWD) is the distance from the end of the contact tip to the work piece (i.e. the steel plate). Sometimes welding documents will reference the electrical stickout (ESO), which is the distance from the end of the contact tip to the top of the arc. In general, ESO is 1/4 in. (6.4 mm) shorter than CTWD. It is very important to hold a consistent CTWD with the gun while welding for good arc stability. Maintain this length within ±1/8 in. (3.2 mm) for CTWD ≤1 in. (25 mm) or within ±1/4 in. (6.4 mm) for CTWD >1 in. (25 mm) during welding.



The normal recommended CTWDs for flux-cored wires are long [1 in. (25 mm) average] compared to short circuit MIG welding [3/8 in. (10 mm) average]. The wire becomes electrically hot as soon as it touches the inside of the contact tip. This longer CTWD for cored wires results in a split second more time of resistance heating in the wire, which allows the core elements to fully react or activate and provide proper protection of the arc. **Note:** If the CTWD is too short, incomplete activation of the core elements may occur, potentially resulting in gas marks or porosity on and in the weld. However, too long of CTWD (with no change to wire feed speed) can cause an unstable arc, increased spatter, and decreased penetration.

WELDING PARAMETERS

Contact Tip To Work Distance (Cont'd)



Some wires and procedures utilize extended stickout distances of 1-1/2 in. to 3-3/4 in. (38 – 95 mm) for higher productivity. The longer CTWDs and resulting increase in resistance heating increases the melt off rate of the wire. Therefore, much faster wire feed speeds must be used, which greatly increases deposition rates. To consistently maintain these long CTWDs at ± 1/4 in. (6.4 mm), nozzle "insulated guides" of various lengths are used. While still using extended CTWDs, the visible portion of wire extended beyond the end of the insulated guide, called the visible stickout (VSO), is much shorter and easier to maintain at a consistent distance. These insulated guides screw onto the end of the gun tube (see picture).

To obtain the proper CTWD when using an insulated guide, first remove the insulated guide from the end of the gun tube. Inch the wire out beyond the end of the contact tip until you obtain the desired CTWD specified for each size and type electrode. Then replace the insulated guide.

When using normal CTWDs, "thread protector" insulators are used. This allows the end of the contact tip to extend beyond them, while protecting the gun tube's threads from spatter buildup.

WARNING: When using thread protectors, the protruding tip should NOT be allowed to touch the work, as it is electrically "hot".

Wire Feed Speed

Wire feed speed (WFS) is the rate at which the Innershield electrodes are fed into the joint, measured in inches per minute (in/min or ipm) or meters per minute (m/min). As WFS increases, so does the deposition rate (lbs/hr or kg/hr). Welding current (measured in amps) and resulting penetration levels are directly related to wire feed speed rates. Higher WFS results in more amperage and more penetration, while lower WFS results in less amperage and less penetration. With CV output, WFS is a more precise weld parameter or setting to use than current, as current varies on CV. Consumable literature often lists approximate currents for specific wire diameters at various WFS levels.

WELDING PARAMETERS

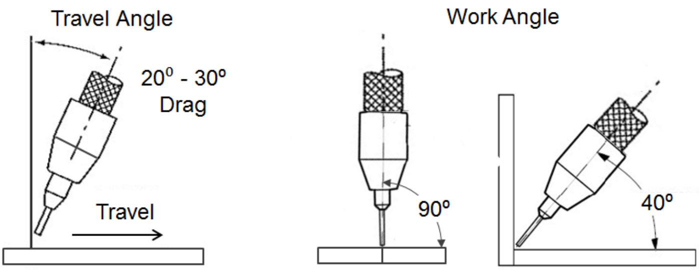
Wire Feed Speed (Cont'd)
Adjust the wire speed using the WFS control on the wire feeder. If the wire feeder does not have a WFS meter or a scaled WFS knob, the wire speed may be measured maually. First disconnect the work clamp from the weld circuit. Then pull the gun trigger and feed the the wire for six seconds, then measure the length fed out and multiply by ten to get the WFS in inches per minute (in/min) or meters per minute (m/min). Set WFS to the suggested rate (see "Operating Guide" section of booklet). The approximate amperage corresponding to each WFS at the specified CTWD is also listed in Operating Guide. Amperage depends on wire feed speed and CTWD. If CTWD is shortened, amperage will increase.

WARNING: When inching, the wire is always electrically "hot" to ground, except when using the "cold inch" feature on wire feeders equipped with this option.

Gun Angles
The angles at which you hold the electrode and gun are important to weld quality. These include the travel angle and work angle, both measured in degrees.

Travel angle is the angle between the electrode and a line perpendicular to the surface of work piece, as measured from the weld side view. Depending on the welding process, use either a "drag" travel angle or a "push" travel angle. The general rule is "drag slag and push gas". Therefore, always use a drag travel angle of typically 20° to 30° with flux cored electrodes. Do not use a push travel angle, as this greatly increases the chance of rolling slag ahead of the puddle and trapping it underneath. Pushing can also cause the arc to ride on top of puddle instead of in front of it, resulting in less penetration.

Work angle is the angle between the electrode and surface of work piece, as measured from the weld end view. For a butt joint, typically use a 90° work angle and for a corner, tee or lap joint, typically use a 40° to 45° work angle (although work angles may vary between different passes of a multiple pass weld). The travel and work angles used with Innershield electrodes are generally the same as used with stick electrodes.



WELDING PARAMETERS

Travel Speed

Travel speed is the rate at which the electrode is moved along the weld joint, measured in inches per minute (ipm) or cm/min. As in all welding processes, use a travel speed which keeps the arc at the front edge of the weld puddle and produces the desired weld size. Maintain a uniform travel speed. The best way to do this is to maintain a uniform distance between the electrode and the molten slag behind the electrode. Travel speed is usually faster with Innershield electrodes than with stick electrodes because of the higher deposit rates. Average travel speeds with Innershield are 6 to 15 in/min (15 to 38 cm/min), compared to stick welding at 4 to 10 in/min (10 to 25 cm/min).

With semiautomatic welding, travel speed is typically measured while welding (divide the length of weld made (in inches or cm) by the time it took to make the weld (in minutes – likely need to convert weld time from seconds to minutes). However, travel speed can also be estimated. The “Bartonian Conversion Factor” can be used to estimate travel speeds of single pass fillet welds, using deposition rate and a conversion factor. Deposition rate is related to wire feed speed and is listed in the “Operating Guide” section of this booklet.

Bartonian Conversion Factor for Steel

Travel Speed (in./min.) = Deposition Rate (lbs/hr) x “B”

5/16 in. fillet	B = 1.00	(fillets based on leg size)
1/4 in. fillet	B = 1.56	
3/16 in. fillet	B = 2.77	
1/8 in. fillet	B = 6.23	

“B” should not be less than 1.00. Traveling slower to put in a larger weld (making B<1) can lead to lack of fusion at the root of weld and trapped slag.

WELDING TECHNIQUES

Starting and Stopping the Arc

With the proper visible CTWD set, position the gun with the electrode lightly touching the work. Avoid pushing the electrode into the joint before starting the arc. Press the gun trigger to start the weld. Release the trigger and pull the gun from the work to stop the arc. Some welders accustomed to manual welding with stick electrode tend to push the electrode into the joint as it burns away. Since the wire is mechanically fed, this must be avoided.

WELDING TECHNIQUES

Handling Poor Fit-Up

Innershield electrodes bridge gaps in the weld joint better than most other welding processes. Poor fit up may require a small, temporary increase in CTWD or a reduction in WFS setting. With CV output, both adjustments will decrease current, which helps reduce penetration and burnthrough, better allowing the weld metal to bridge the gap.

Use a Drag Technique

Always use a drag travel angle with Innershield electrodes. Tilt the gun back away from the weld puddle in the direction of travel at about the same as required with SMAW (stick) welding (i.e. 20º to 30º). If slag tends to run ahead of the arc, increase the drag angle. However, if the drag angle becomes too great, erratic arc action and excessive arc blow will result in porosity and poor bead shape.

Work Angle and Wire Placement

For horizontal fillet welds the work angle should be about 40º. Wire placement depends on the size of the fillet weld. With 1/4 in. (6 mm) and smaller fillets, point the wire right into the root of the joint. For best bead shape on 5/16 in. (8 mm) and larger horizontal fillets, point the wire at the bottom plate one or two wire diameters away from the root of the joint. Using this position, the molten metal washes onto the vertical plate, giving you even leg sizes.

Making Out-of-Position Welds

In regards to welding positions, it can be helpful to think of arc welding in terms of liquid metal and gravity. When you are welding "in position" (i.e. flat and horizontal), you are working with gravity. You can have a large molten weld puddle made with large diameter electrodes and very high deposition rate procedures. However, the situation dramatically changes when you are welding "out-of-position" (i.e. vertical and overhead) and working against gravity. Now you must have a small, fast freezing puddle and are limited to smaller diameter electrodes operating at lower deposition rate procedures.

Smaller diameters of Innershield electrodes, 5/64 in. (2.0 mm) and less, are recommended for out-of-position welding. In addition, the electrode must have a fast freezing slag system. Not all Innershield electrodes have the appropriate type of slag system. The electrodes that CAN be used for all position welding include:

- Innershield NR-152[(1)(2)]
- Innershield NR-203 MP[(5)]
- Innershield NR-203Ni(1%)[(5)]
- Innershield NR-203 Ni C Plus-H[(5)]
- Innershield NR-207[(3)]
- Innershield NR-208-H[(3)]
- Pipeliner NR-207+[(3)]
- Pipeliner NR-208-XP[(3)]
- Pipeliner NR-208-P[(3)]
- Innershield NR-211-MP[(2)]
- Innershield NR-212[(2)(5)]
- Innershield NR-232[(4)]
- Innershield NR-233[(4)]
- Innershield NR-440Ni2[(5)]
- Innershield NR-555[(5)]

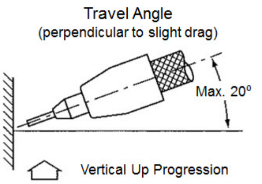
(1) Innershield NR-152 is limited to single pass welding only.
(2) These electrodes have a maximum plate thickness limitation.
(3) These electrodes have a more fluid slag system, making them ideal for vertical down pipe welding. However, they are not recommended for vertical up welding, as the puddle would be very difficult to handle.
(4) These electrodes are not recommended for vertical down welding because of their heavy slag systems.
(5) These electrodes operate well with both vertical up and vertical down progression.

WELDING TECHNIQUES

When welding out-of-position, do not whip, break the arc, move out of the puddle or move too fast in any direction. Use WFSs in the lower portion of the electrode's range. General techniques are illustrated below. Experience will show how much hesitation and upward step is required for high quality welds.

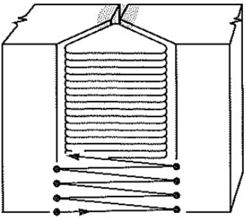
Vertical-Up Progression

Generally, keep the wire nearly perpendicular to the joint as illustrated. Up to a maximum 20° travel angle above perpendicular (i.e. the maximum recommended drag angle) may be required if porosity becomes a problem.



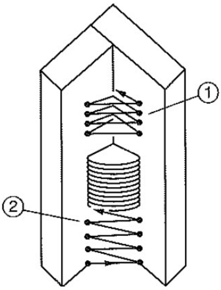
Vertical-Up Groove Welds

1. Make a distinct hesitation at the outer edges of bevel (i.e. the toes of weld).
2. Travel fairly quickly across the face of the weld.
3. Minimize each upward step across the weld face. Do not step up at the edges.
4. Do not weave wider than 3/4 in. (20 mm). If the joint is wider than that, then use a split weave technique.



Vertical-Up Fillet Welds

1. On 1/4 in. (6.0 mm) welds, a short side-to-side motion is used.
2. On larger welds, use a triangular weave pattern (see number 1 in the sketch), with a distinct hesitation at the outer edges for the first pass. Make sure during the leading motion of the triangular weave that the arc is focused into the root of the joint (and not riding on the puddle), in order to achieve root penetration. The first pass should have a face width of 5/16 in. - 3/8 in. (8 – 10 mm). For the second and later passes, use a side-to-side weave (see number 2 in the sketch) similar to that used for groove welds.



Vertical-Up Stringer Beads

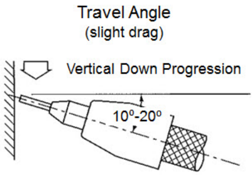
Stringer beads (i.e. a straight travel progression) are more commonly used with electrodes such as Innershield NR-232 and Innershield NR-233 for vertical up welding. They should be used with a slight drag travel angle and using a shake technique (not a weave) in order to flatten out the weld face. Stringer beads are used for both groove and fillet welds. Note that the NR-203 family of electrodes (including NR-440Ni2 and NR-555) do not work well using stringer beads. They require some manipulation of the puddle in order to flatten out the weld face.

WELDING TECHNIQUES

Overhead Welding
Welds in the overhead position are made with stringer beads using a drag travel angle. A slight weave can be used with groove welds.

Downhill and Vertical-Down Progression
1/4 in. (6 mm) or smaller welds can also be made using downhill and vertical down welding techniques. The excellent high speed welding characteristics are best utilized for low cost single pass welds by positioning the work downhill or vertical down. The work positioned at a 60° downhill angle and using a 5/64 in. or 3/32 in. (2.0 or 2.4 mm) electrode usually provides maximum speed.

Use stringer beads. Do not attempt to weave the electrode. Use WFSs and resulting current levels in the middle to high portion of the electrode's range. Use a 10° to 20° drag travel angle, tipping the electrode up so that arc force helps hold the molten metal in the joint. Move as fast as possible, consistent with desired bead shape. Note that a vertical down progression tends to produce concave welds.



Use electrodes with a lighter slag. Some all position electrodes, such as Innershield NR-232 and Innershield NR-233, are not recommended for downhill and vertical down welding because of their heavy slag systems. In vertical up welding, you stack weld metal on a shelf, with gravity holding back the slag from the leading edge of the puddle. However, with vertical down welding, gravity is constantly pulling the weld metal and slag down. If there is too much slag, it can potentially roll ahead of the weld puddle and get trapped underneath.

Extended Stickout Welding
Because Innershield electrodes do not use a shielding gas, they are not limited to a maximum CTWD of approximately 1-1/4 in. (30 mm) (i.e. the approximate range of shielding gas flow which still provides complete coverage of the arc). Therefore, much longer CTWDs of 3 in. to 4 in. (75 to 100 mm) can be used, which produces a large increase in deposition rate. The extra length of electrode beyond the contact tip has greater electrical resistance.

This increased resistance heats the electrode to a higher temperature, increasing its melt-off rate, which in turn requires higher WFSs. Thus the result is a significant increase in deposition rates and potentially lower welding costs. Using a long CTWD also reduces penetration.

WELDING TECHNIQUES

Extended Stickout Welding (Cont'd)
Extended stickout welding is best suited to large diameter, high deposition Innershield electrodes, such as 3/32 in. (2.4 mm) and 0.120 in. (3.0 mm) Innershield NS-3M. It is generally limited to 5/16 in. (8.0 mm) and larger flat fillets, multiple pass flat fillets and the fill passes of flat deep groove butt joints.

Extended stickout guides are used to maintain a consistent CTWD (see "Contact Tip to Work Distance" section for more details).

OPERATING GUIDE

Welding Procedures
The suggested welding procedures listed in this publication are not intended to serve as specific procedures for any application. These suggested procedures represent the approximate procedure range of each individual electrode. Arc voltage and/or wire feed speed may need to be adjusted depending upon welding position, type of weld, base steel surface condition or other factors. In general, use the highest voltage possible consistent with porosity-free welds.

For more information on a particular Innershield electrode, see the Lincoln Electric website. Search under "Consumables" – "Flux-Cored Wires, Self-Shielded".

Suggested Welding Procedures

Wire, Polarity, AWS Class, CTWD in. (mm), Wire Weight	Wire Feed Speed in/min (m/min)	Arc Voltage (volts)	Approx. Current (amps)	Deposit Rate lbs/hr (kg/hr)
3/32 in. (2.4mm) NR-5(1) (DC+) E70T-3, E70T3S 1-1/4 (32) 1.60 lbs/1000 in.	100 (2.5) 150 (3.8) 200 (5.1) 250 (6.4)	22 - 23 23 - 24 24 - 25 25 - 26	340 435 510 575	7.8 (3.5) 12.3 (5.6) 16.9 (7.6) 21.4 (9.7)
0.120 in. (3.0 mm) NR-5(1) (DC+) E70T-3, E70T3S 1-1/4 (32) 2.46 lbs/1000 in.	130 (3.3) 165 (4.2) 205 (5.2) 255 (6.5)	22 - 23 23 - 24 24 - 25 25 - 26	500 600 700 800	16.7 (7.6) 20.9 (9.5) 25.6 (11.6) 31.5 (14.3)
3/32 in. (2.4 mm) NR-131(1) (DC-) E70T-10, E70T10S 1-1/2 (38) 1.58 lbs/1000 in.	150 (3.8) 200 (5.1) 250 (6.4) 350 (8.9) 425 (10.8)	25 - 26 25 - 27 26 - 27 26 - 28 27 - 28	390 490 570 720 810	11.6 (5.3) 15.6 (7.1) 19.6 (8.9) 27.6 (12.5) 33.6 (15.2)
0.045 in. (1.1 mm) NR-152(1) (DC-) E71T-14, E71T14S 5/8 (16) 0.39 lbs/1000 in.	60 (1.5) 90 (2.3) 120 (3.0) 150 (3.8)	14 - 15 15 - 16 16 - 17 17 - 18	95 135 160 180	1.1 (0.5) 1.8 (0.8) 2.5 (1.1) 3.2 (1.4)

(1) Single pass welding only. Key: CTWD = ESO + 1/4 in. (6 mm)

NOTE: These are typical operating procedures only and are not intended to serve as specific procedures for any applications.

OPERATING GUIDE

Suggested Welding Procedures

Wire, Polarity, AWS Class, CTWD in. (mm), Wire Weight	Wire Feed Speed in/min (m/min)	Arc Voltage (volts)	Approx. Current (amps)	Deposit Rate lbs/hr (kg/hr)
0.062 in. (1.6 mm) NR-152[1] (DC+) E71T-14, E71T14S 5/8 (16) 0.74 lbs/1000 in.	30 (0.8) 40 (1.0) 50 (1.3) 70 (1.8) 110 (2.8)	13 - 14 13 - 14 15 - 16 16 - 17 19 - 20	90 115 140 185 265	1.2 (0.5) 1.6 (0.7) 2.0 (0.9) 2.8 (1.3) 4.4 (2.0)
0.068 in. (1.7 mm) NR-152[1] (DC-) E71T-14, E71T14S 3/4 (20) 0.91 lbs/1000 in.	30 (0.8) 40 (1.0) 50 (1.3) 60 (1.5) 80 (2.0) 110 (2.8)	13 - 14 13 - 14 14 - 15 15 - 16 16 - 17 20 - 21	68 95 120 145 190 240	1.4 (0.6) 1.9 (0.9) 2.4 (1.1) 2.9 (1.3) 3.9 (1.8) 5.4 (2.4)
0.068 in. (1.7 mm) NR-203MP (DC-) E71T-8J, E71T8-A4-CS3-H16 1 (25) 0.78 lbs/1000 in.	70 (1.8) 90 (2.3) 120 (3.0) 140 (3.5) 150 (3.8)	16 - 17 18 - 19 20 - 21 21 - 22 23 - 24	145 180 225 255 265	2.3 (1.0) 3.2 (1.5) 4.3 (2.0) 4.8 (2.2) 5.1 (2.3)
5/64 in. (2.0 mm) NR-203MP (DC-) E71T-8J, E71T8-A4-CS3-H16 1 (25) 1.03 lbs/1000 in.	50 (1.3) 70 (1.8) 90 (2.3) 110 (2.8) 120 (3.0) 140 (3.5)	16 - 17 18 - 19 19 - 20 20 - 21 21 - 22 22 - 23	130 180 220 260 280 310	1.9 (0.9) 2.9 (1.3) 4.2 (1.9) 5.3 (2.4) 5.9 (2.7) 6.8 (3.1)
5/64 in. (2.0 mm) **Pipeliner NR-208-P** (DC-) E81T8-G, E81T8-A4G 3/4 (20) 1.04 lbs/1000 in.	70 (1.8) 90 (2.3) 110 (2.8) 130 (3.3)	18 - 19 19 - 20 19 - 20 20 - 21	210 240 270 305	3.6 (1.6) 4.8 (2.2) 6.0 (2.7) 6.7 (3.0)
5/64 in. (2.0 mm) **NR-203 Nickel (1%)** (DC-) E71T8-Ni1, E71T8-A2-Ni1-H16 1 (25) 1.02 lbs/1000 in.	50 (1.3) 70 (1.8) 90 (2.3) 110 (2.8) 120 (3.0) 140 (3.5)	16 - 17 18 - 19 19 - 20 20 - 21 21 - 22 22 - 23	145 195 240 275 290 310	2.3 (1.0) 3.3 (1.5) 4.3 (2.0) 5.3 (2.4) 5.8 (2.6) 6.9 (3.0)
5/64 in. (2.0 mm) **NR-203 Ni C Plus-H** (DC-) E71T8-K2, E71T8-A2-K2-H8 1 (25) 1.09 lbs/1000 in.	50 (1.3) 70 (1.8) 90 (2.3) 110 (2.8)	16 - 17 17 - 18 19 - 20 20 - 21	115 170 210 245	2.3 (1.0) 3.3 (1.5) 4.4 (2.0) 5.5 (2.5)
0.068 in. (1.7 mm) NR-207[2] (DC-) E71T8-K6, E71T8-A2-K6-H16 1 (25) 0.78 lbs/1000 in.	80 (2.0) 90 (2.3) 105 (2.7) 120 (3.0) 145 (3.7) 170 (4.3)	17 - 18 17 - 18 18 - 19 19 - 20 21 - 22 21 - 22	190 205 230 245 275 295	3.0 (1.4) 3.4 (1.5) 4.0 (1.8) 4.5 (2.0) 5.5 (2.5) 6.4 (2.9)

(1) Single pass welding only. Key: CTWD = ESO + 1/4 in. (6 mm)
(2) Electrode designed for pipe welding.

NOTE: These are typical operating procedures only and are not intended to serve as specific procedures for any applications.

OPERATING GUIDE

Suggested Welding Procedures

Wire, Polarity, AWS Class, CTWD in. (mm), Wire Weight	Wire Feed Speed in/min (m/min)	Arc Voltage (volts)	Approx. Current (amps)	Deposit Rate lbs/hr (kg/hr)
5/64 in. (2.0 mm) NR-207(2) (DC-) E71T-8-K6, E71T8-A2-K6-H16 1 (25) 1.04 lbs/1000 in.	70 (1.8) 80 (2.0) 90 (2.3) 110 (2.8) 130 (3.3)	17 - 18 18 - 19 18 - 19 20 - 21 20 - 21	205 225 240 275 300	3.4 (1.5) 3.9 (1.8) 4.5 (2.0) 5.5 (2.5) 6.5 (2.9)
5/64 in. (2.0 mm) NR-208-H(2) (DC-) E91T8-G-H8, E91T8-AG-G-H8 1 (25) 1.04 lbs/1000 in.	70 (1.8) 80 (2.0) 90 (2.3) 110 (2.8) 130 (3.3)	16 - 17 17 - 18 18 - 19 19 - 20 19 - 20	195 220 235 275 295	3.2 (1.5) 3.9 (1.8) 4.5 (2.0) 5.5 (2.5) 6.5 (2.9)
5/64 in. (2.0 mm) **Pipeliner NR-207+**(2) (DC-) E71T8-K6, E71T8-A2-K6 3/4 (20) 1.04 lbs/1000 in.	70 (1.8) 90 (2.3) 110 (2.8) 130 (3.3)	17 - 18 18 - 19 20 - 21 20 - 21	205 240 275 300	3.4 (1.5) 4.5 (2.0) 5.5 (2.5) 6.5 (2.9)
5/64 in. (2.0 mm) **Pipeliner NR-208-XP**(2) (DC-) E81T8-G, E81T8-A4-G 3/4 (20) 1.04 lbs/1000 in.	70 (1.8) 90 (2.3) 110 (2.8) 130 (3.3)	17 - 18 18 - 19 19 - 20 19 - 20	195 235 265 295	4.0 (1.8) 4.8 (2.2) 6.0 (2.7) 7.6 (3.5)
0.030 in. (0.8 mm) **NR-211-MP**(3) (DC-) E71T-11, E71T11-AZ-CS3 1/2 (13) 0.250 lbs/1000 in.	50 (1.3) 100 (2.5) 150 (3.8) 200 (5.1) 250 (6.4) 300 (7.6)	13 - 14 13 - 14 14 - 15 14 - 15 15 - 16 18 - 19	30 60 80 100 130 140	0.4 (0.2) 0.8 (0.4) 1.2 (0.5) 1.7 (0.8) 2.1 (1.0) 2.6 (1.2)
0.035 in. (0.9 mm) **NR-211-MP**(3) (DC-) E71T-11, E71T11-AZ-CS3 1/2 - 5/8 (13 - 16) 0.250 lbs/1000 in.	50 (1.3) 70 (1.8) 110 (2.8) 150 (3.8) 200 (5.1)	14 - 15 15 - 16 16 - 17 17 - 18 18 - 19	30 60 115 130 155	0.7 (0.3) 1.0 (0.5) 1.3 (0.6) 1.7 (0.8) 2.5 (1.1)
0.045 in. (1.1 mm) **NR-211-MP**(3) (DC-) E71T-11, E71T11-AZ-CS3 5/8 (16) 0.39 lbs/1000 in.	70 (1.8) 90 (2.3) 110 (2.8) 130 (3.3)	15 - 16 16 - 17 17 - 18 18 - 19	120 140 160 170	1.1 (0.5) 1.7 (0.8) 2.3 (1.0) 2.7 (1.2)
0.068 in. (1.7 mm) **NR-211-MP**(3) (DC-) E71T-11, E71T11-AZ-CS3 3/4 - 1-1/4 (19 - 32) 0.89 lbs/1000 in.	40 (1.0) 75 (1.9) 130 (3.3) 175 (4.4)	15 - 16 18 - 19 20 - 21 23 - 24	125 190 270 300	1.7 (0.8) 3.4 (1.5) 6.1 (2.8) 8.4 (3.8)
5/64 in. (2.0 mm) **NR-211-MP**(4) (DC-) E71T-11, E71T11-AZ-CS3 3/4 - 1-1/4 (19 - 32) 1.17 lbs/1000 in.	50 (1.3) 75 (1.9) 120 (3.0) 160 (4.1)	16 - 17 18 - 19 20 - 21 22 - 23	180 235 290 325	2.9 (1.3) 4.5 (2.0) 7.4 (3.4) 10.0 (4.5)

(2) Electrode designed for pipe welding. Key: CTWD = ESO + 1/4 in. (6 mm)
(3) Electrode limited to maximum 5/16 in. (7.9 mm) plate thickness.
(4) Electrode limited to maximum 1/2 in. (12.7 mm) plate thickness.

NOTE: These are typical operating procedures only and are not intended to serve as specific procedures for any applications.

OPERATING GUIDE

Suggested Welding Procedures

Wire, Polarity, AWS Class, CTWD in. (mm), Wire Weight	Wire Feed Speed in/min (m/min)	Arc Voltage (volts)	Approx. Current (amps)	Deposit Rate lbs/hr (kg/hr)
3/32 in. (2.4 mm) **NR-211-MP**(4) (DC-) E71T-11, E71T11-AZ-CS3 3/4 - 1-1/4 (19 - 32) 1.66 lbs/1000 in.	50 (1.3) 75 (1.9) 100 (2.5) 130 (3.3)	16 - 17 19 - 20 20 - 21 22 - 23	245 305 365 400	4.2 (1.9) 6.4 (2.9) 8.7 (3.9) 11.3 (5.1)
0.045 in. (1.1 mm) NR-212(5) (DC-) E71TG-G, E71TG-AZ-G-H16 5/8 (16) 0.39 lbs/1000 in.	55 (1.4) 70 (1.8) 90 (2.3) 110 (2.8) 130 (3.3) 150 (3.8)	14 - 15 15 - 16 16 - 17 17 - 18 18 - 19 19 - 20	75 95 115 135 155 170	1.1 (0.5) 1.4 (0.6) 1.8 (0.8) 2.2 (1.0) 2.6 (1.2) 3.0 (1.4)
0.068 in. (1.7 mm) NR-212(5) (DC-) E71TG-G, E71TG-AZ-G-H16 1 (25) 0.82 lbs/1000 in.	60 (1.5) 75 (1.9) 90 (2.3) 120 (3.0) 150 (3.8) 175 (4.4)	16 - 17 18 - 19 19 - 20 20 - 21 21 - 22 22 - 23	145 180 200 230 255 275	2.4 (1.1) 3.2 (1.4) 3.8 (1.7) 5.2 (2.4) 6.4 (2.9) 7.5 (3.4)
5/64 in. (2.0 mm) NR-212(5) (DC-) E71TG-G, E71TG-AZ-G-H16 1 (25) 1.06 lbs/1000 in.	60 (1.5) 75 (1.9) 90 (2.3) 110 (2.8) 130 (3.3) 150 (3.8)	16 - 17 18 - 19 19 - 20 20 - 21 21 - 22 22 - 23	200 225 245 275 300 325	3.3 (1.5) 4.1 (1.9) 5.0 (2.3) 6.2 (2.8) 7.3 (3.3) 8.4 (3.8)
0.068 (1.7 mm) NR-232 (DC-) E71T-8, E71T8-A2-CS3-H16 1 (25) 0.75 lbs/1000 in.	110 (2.8) 130 (3.3) 150 (3.8) 170 (4.3) 195 (5.0) 250 (6.4) 320 (8.1)	18 - 20 19 - 21 19 - 21 20 - 22 23 - 24 23 - 24 25 - 27	195 225 250 270 300 350 400	3.9 (1.8) 4.6 (2.1) 5.3 (2.4) 6.1 (2.8) 7.0 (3.2) 9.0 (4.1) 11.4 (5.2)
0.072 in. (1.8 mm) NR-232 (DC-) E71T-8, E71T8-A2-CS3-H16 1 (25) 0.78 lbs/1000 in.	80 (2.0) 140 (3.6) 155 (3.9) 170 (4.3) 250 (6.4) 290 (7.4)	16 - 18 18 - 21 19 - 22 20 - 23 22 - 24 23 - 25	130 225 240 255 315 350	3.3 (1.5) 5.5 (2.5) 6.0 (2.7) 6.5 (3.0) 9.6 (4.4) 11.0 (5.0)
5/64 in. (2.0 mm) NR-232 (DC-) E71T-8, E71T8-A2-CS3-H16 1 (25) 1.00 lbs/1000 in.	60 (1.5) 70 (1.8) 115 (2.9) 120 (3.0) 130 (3.3) 150 (3.8) 180 (4.6)	16 - 17 16 - 17 19 - 20 19 - 20 20 - 21 20.5 - 21.5 22 - 23	145 170 260 270 285 320 365	2.7 (1.2) 3.2 (1.5) 5.5 (2.5) 5.7 (2.6) 6.2 (2.8) 7.2 (3.3) 8.7 (4.0)
1/16 in. (1.6 mm) NR-233 (DC-) E71T-8, E71T8-A2-CS3-H16 1 (25) 0.59 lbs/1000 in.	150 (3.8) 200 (5.1) 250 (6.4) 300 (7.6) 350 (8.9)	17 - 19 19 - 21 21 - 23 23 - 25 25 - 27	220 245 270 295 315	4.2 (1.9) 5.4 (2.5) 6.6 (3.0) 7.7 (3.5) 9.4 (4.3)

(4) Electrode limited to maximum 1/2 in. (12.7 mm) plate thickness.
(5) Electrode limited to maximum 3/4 in. (19 mm) plate thickness.

Key: CTWD = ESO + 1/4 in. (6 mm)

NOTE: These are typical operating procedures only and are not intended to serve as specific procedures for any applications.

OPERATING GUIDE

Suggested Welding Procedures

Wire, Polarity, AWS Class, CTWD in. (mm), Wire Weight	Wire Feed Speed in/min (m/min)	Arc Voltage (volts)	Approx. Current (amps)	Deposit Rate lbs/hr (kg/hr)
0.072 in. (1.8 mm) NR-233 (DC-) E71T-8, E71T8-A2-CS3-H16 1 (25) 0.74 lbs/1000 in.	100 (2.5) 150 (3.8) 200 (5.1) 250 (6.4) 300 (7.6)	17 - 18 18 - 19 20 - 21 22 - 23 23 - 24	185 250 295 330 355	3.6 (1.6) 5.4 (2.5) 7.1 (3.2) 8.9 (4.0) 10.6 (4.8)
5/64 in. (2.0 mm) NR-233 (DC-) E71T-8, E71T8-A2-CS3-H16 1 (25) 0.93 lbs/1000 in.	90 (2.3) 125 (3.2) 150 (3.8) 200 (5.1) 240 (6.1)	18 - 19 19 - 20 20 - 21 21- 22 22 - 23	210 260 300 340 380	4.1 (1.9) 5.6 (2.5) 6.7 (3.0) 9.0 (4.1) 10.8 (4.9)
5/64 in. (2.0 mm) NS-3M (DC+) E70T-4, E70T4-AZ-CS3 2-1/4 (57)(6) 1.03 lbs/1000 in.	200 (5.1) 240 (6.1) 260 (6.6) 300 (7.6)	29 - 31 30 - 32 30 - 32 31 - 33	280 315 330 350	10.1 (4.6) 12.1 (5.5) 13.2 (6.0) 15.2 (6.9)
3/32 in. (2.4 mm) NS-3M (DC+) E70T-4, E70T4-AZ-CS3 3 (76)(6) 1.53 lbs/1000 in.	110 (2.8) 150 (3.8) 185 (4.7) 230 (5.8) 275 (7.0)	28 - 30 29 - 31 30 - 32 31 - 33 32 - 34	250 300 350 400 450	8.2 (3.7) 11.7 (5.3) 14.6 (6.6) 18.3 (8.3) 22.0 (10.0)
0.120 in. (3.0 mm) NS-3M (DC+) E70T-4, E70T4-AZ-CS3 3 (76)(6) 2.34 lbs/1000 in.	140 (3.6) 175 (4.4) 200 (5.1) 225 (5.7)	28 - 30 29 - 31 30 - 32 31 - 33	380 450 500 550	15.5 (7.0) 20.0 (9.1) 23.2 (10.5) 26.2(11.9)
0.120 in. (3.0 mm) NS-3M (DC+) E70T-4, E70T4-AZ-CS3 4 (102)(6) 2.34 lbs/1000 in.	210 (5.3) 250 (6.4) 300 (7.6) 355 (9.0)	35 - 37 36 - 38 37 - 39 38 - 40	450 500 550 600	25.0 (11.3) 29.0 (13.2) 34.0 (15.4) 39.5 (18.0)
5/64 in. (2.0 mm) NR-305 (DC+) E70T-6, E70T6-A2-CS3-H16 1-1/2 (38) 1.07 lbs/1000 in.	175 (4.4) 220 (5.6) 260 (6.6) 300 (7.6) 325 (8.3)	20 - 22 21 - 23 22 - 24 24 - 26 25 - 27	300 330 360 375 400	8.8 (4.0) 11.1 (5.0) 13.1 (5.9) 15.2 (6.9) 16.4 (7.4)
3/32 in. (2.4 mm) NR-305 (DC+) E70T-6, E70T6-A2-CS3-H16 1-3/4 (44) 1.39 lbs/1000 in.	160 (4.1) 240 (6.1) 300 (7.6) 400 (10.2)	21 - 23 24 - 26 27 - 29 33- 35	330 425 475 525	11.0 (5.0) 16.7 (7.6) 21.0 (9.5) 28.0 (12.7)
5/64 in. (2.0 mm) NR-311 (DC-) E70T-7, E70T7-AZ-CS3 1-1/2 (38) 1.07 lbs/1000 in.	100 (2.5) 160 (4.1) 240 (6.1) 300 (7.6)	20 - 22 24 - 26 25 - 28 27 - 30	190 275 355 410	5.0 (2.3) 8.0 (3.6) 12.4 (5.6) 15.8 (7.2)

(6) Requires extended insulator guides.   Key: CTWD = ESO + 1/4 in. (6 mm)

NOTE: These are typical operating procedures only and are not intended to serve as specific procedures for any applications.

OPERATING GUIDE

Suggested Welding Procedures

Wire, Polarity, AWS Class, CTWD in. (mm), Wire Weight	Wire Feed Speed in/min (m/min)	Arc Voltage (volts)	Approx. Current (amps)	Deposit Rate lbs/hr (kg/hr)
3/32 in. (2.4 mm) NR-311	75 (1/9)	20 - 22	200	5.4 (2.5)
(DC-) E70T-7,	135 (3.4)	23 - 26	300	10.2 (4.6)
E70T7-AZ-CS3	150 (3.8)	24 - 27	325	11.4 (5.2)
1-3/4 (44)	210 (5.3)	26 - 28	400	16.5 (7.5)
1.62 lbs/1000 in.	270 (6.9)	28 - 30	450	22.0 (10.0)
7/64 in. (2.8 mm) NR-311	100 (2.5)	23 - 26	325	10.0 (4.5)
(DC-) E70T-7,	145 (3.7)	25 - 27	400	14.5 (6.6)
E70T7-AZ-CS3	175 (4.4)	26 - 28	450	18.0 (8.2)
1-3/4 (44)	240 (6.1)	30 - 32	550	25.5 (11.6)
2.05 lbs/1000 in.	300 (7.6)	32 - 34	625	33.0 (15.0)
5/64 in. (2.0 mm) NR-311 Ni	100 (2.5)	21 - 23	170	3.9 (1.8)
(DC-) E80TG-K2,	130 (3.3)	24 - 26	205	5.2 (2.4)
E80TG-A2-K2-H16	160 (4.1)	25 - 27	235	6.5 (3.0)
1-1/4 (32)	200 (5.1)	26 - 28	270	8.3 (3.8)
0.93 lbs/1000 in.	240 (6.1)	27 - 29	295	10.0 (4.5)
3/32 in. (2.4 mm) NR-311 Ni	75 (1.9)	20 - 22	200	4.2 (1.9)
(DC-) E80TG-K2,	125 (3.2)	23 - 25	285	7.5 (3.4)
E80TG-A2-K2-H16	150 (3.8)	25 - 27	330	9.1 (4.1)
1-1/2 (38)	175 (4.4)	26 - 28	365	10.8 (4.9)
1.39 lbs/1000 in.	200 (5.1)	27 - 29	390	12.3 (5.6)
7/64 in. (2.8 mm) NR-311 Ni	100 (2.5)	22 - 24	310	8.4 (3.8)
(DC-) E80TG-K2,	140 (3.6)	24 - 26	370	11.8 (5.4)
E80TG-A2-K2-H16	170 (4.3)	26 - 28	430	14.5 (6.6)
1-3/4 (44)	200 (5.1)	28 - 30	470	17.0 (7.7)
1.89 lbs/1000 in.	240 (6.1)	29 - 31	520	20.4 (9.3)
3/32 in. (2.4 mm) NR-FAB-70	100 (2.5)	22 - 24	265	6.1 (2.8)
(DC-) E70T7-G,	125 (3.2)	23 - 25	320	7.9 (3.6)
E70T7-A2-G-H16	150 (3.8)	25 - 27	355	10.1 (4.6)
1-1/2 (38)	180 (4.6)	25 - 27	380	12.2 (5.5)
1.46 lbs/1000 in.	210 (5.3)	27 - 29	425	14.3 (6.5)
1/16 in. (1.6 mm) NR-440Ni2	90 (2.3)	17 - 18	160	2.5 (1.1)
(DC-) E71T8-Ni2-JH8,	100 (2.5)	18 - 19	170	2.8 (1.2)
E71T8-A4-Ni2-H8	110 (2.8)	18 - 19	180	3.1 (1.4)
3/4 (20)	120 (3.0)	19 - 20	195	3.5 (1.6)
0.67 lbs/1000 in.	130 (3.3)	19 - 20	210	3.7 (1.7)
5/64 in. (2.0 mm) NR-440Ni2	70 (1.8)	17 - 18	205	3.2 (1.5)
(DC-) E71T8-Ni2-JH8,	80 (2.0)	18 - 19	225	3.6 (1.6)
E71T8-A4-Ni2-H8	90 (2.3)	18 - 19	240	4.2 (1.9)
1 (25)	100 (2.5)	19 - 20	260	4.7 (2.1)
0.98 lbs/1000 in.	120 (3.0)	20 - 21	295	5.6 (2.5)

Key: CTWD = ESO + 1/4 in. (6 mm)

NOTE: These are typical operating procedures only and are not intended to serve as specific procedures for any applications.

OPERATING GUIDE

Suggested Welding Procedures

Wire, Polarity, AWS Class, CTWD in. (mm), Wire Weight	Wire Feed Speed in/min (m/min)	Arc Voltage (volts)	Approx. Current (amps)	Deposit Rate lbs/hr (kg/hr)
1/16 in. (1.6 mm) NR-555 (DC-) E81T8-G, E81T8-A5-K8-H8 7/8 (22) 0.68 lbs/1000 in.	75 (1.9) 90 (2.3) 100 (2.5) 110 (2.8)(7) 120 (3.0)	16 - 17 17 - 18 17 - 18 18 - 19 19 - 20	145 160 175 185 200	2.2 (1.0) 2.7 (1.2) 3.1 (1.4) 3.4 (1.5) 3.6 (1.6)
5/64 in. (2.0 mm) NR-555 (DC-) E81T8-G, E81T8-A5-K8-H8 7/8 (22) 0.98 lbs/1000 in.	75 (1.9) 90 (2.3) 100 (2.5) 110 (2.8)(7) 120 (3.0)	16 - 17 17 - 18 17 - 18 18 - 19 19 - 20	185 215 230 245 260	3.0 (1.4) 4.0 (1.8) 4.8 (2.0) 5.5 (2.5) 5.8 (2.6)

(7) Optimal settings. Key: CTWD = ESO + 1/4 in. (6 mm)

NOTE: These are typical operating procedures only and are not intended to serve as specific procedures for any applications.

OPERATING GUIDE

EFFECT OF WELDING PARAMETERS

The four major welding parameters with Innershield welding are arc voltage, wire feed speed (WFS), travel speed and contact tip to work distance (CTWD). These variables were explained in detail earlier in this booklet in the "WELDING PARAMETERS" section. Each of these parameters is interdependent. If one is changed, usually the other three must also be adjusted in order to maintain a stable arc and good weld quality.

Arc Voltage

If WFS, travel speed and CTWD are held constant, changing the arc voltage will have the following effects:

1. Higher arc voltage increases arc length and broadens the arc cone, which results in a wider and flatter bead.
2. Excessive arc voltage causes porosity.
3. Lower arc voltage decreases arc length and narrows the arc cone, which results in a narrower and more convex bead.
3. Too low of arc voltage causes a convex, ropey bead.
4. Extremely low voltage will cause the wire to stub on the plate. That is, the wire will dive through the molten metal and strike the joint bottom, tending to push the gun up.

Wire Feed Speed (WFS) (which controls welding current)

If arc voltage, travel speed and CTWD are held constant, WFS variations have the following major effects:

1. Increasing the WFS increases melt-off and deposition rates.
2. Excessive WFS produces convex beads. This wastes weld metal and results in poor appearance. As WFS is increased, the arc voltage must also be increased to maintain proper bead shape.
3. Increasing WFS also increases the maximum voltage which can be used without porosity. Lowering the WFS requires lowering the voltage to avoid porosity.
4. If WFS is too low, the arc will burn towards (and possibly into) the contact tip.

Travel Speed

If arc voltage, WFS and CTWD are held constant, travel speed variations have the following major effects:

1. Too fast of a travel speed increases the convexity of the bead and causes uneven edges.
2. Too slow of a travel speed results in slag interference, slag inclusions and a rough, uneven bead.

Contact Tip to Work Distance (CTWD)

If the voltage and wire feed speed setting and the travel speed are held constant, variations in CTWD have the following major effects:

1. Increasing CTWD reduces the welding current.
2. Decreasing CTWD increases current.
3. Increasing CTWD reduces actual arc voltage and results in more convex beads and reduces the tendency of porosity.
4. Momentarily increasing CTWD can be used to reduce burnthrough tendency when poor joint fit-up conditions are encountered.

OPERATING GUIDE

TROUBLESHOOTING INNERSHIELD WELD PROBLEMS

Innershield welds that are properly made have excellent appearance. However, follow the tips in this weld troubleshooting guide when the bead appearance is not as desired.

To Eliminate Porosity (In order of importance)

1. Clean the joint of moisture, rust, oil, paint and other contaminants
2. Decrease voltage
3. Increase CTWD
4. Increase WFS
5. Decrease drag angle
6. Decrease travel speed

To Eliminate a Ropey Convex Bead (In order of importance)

1. Increase voltage (within wire specifications)
2. Decrease CTWD
3. Decrease WFS
4. Decrease travel speed
5. Decrease drag angle

To Reduce Spatter (In order of importance)

1. Adjust voltage
2. Decrease drag angle
3. Decrease CTWD
4. Increase WFS
5. Decrease travel speed

To Correct Poor Penetration (In order of importance)

1. Decrease CTWD
2. Increase WFS
3. Decrease voltage
4. Decrease travel speed
5. Decrease drag angle

To Minimize Arc Blow (In order of importance)

Arc blow occurs when the arc stream does not follow the shortest path between the electrode and the work piece.

1. Move work connection locations
2. Decrease drag angle
3. Increase CTWD
4. Decrease WFS and voltage
5. Decrease travel speed

To Eliminate Stubbing (In order of importance)

Stubbing occurs when the wire drives through the molten puddle and hits the bottom plate tending to push the gun up.

1. Increase voltage
2. Decrease WFS
3. Decrease CTWD
4. Decrease drag angle

NOTE: Equipment troubleshooting instructions are included in the operating manuals for the wire feeder and power source. Be sure to confirm the equipment is operating properly.

TROUBLESHOOTING INNERSHIELD WELD PROBLEMS

To Eliminate Trapped Slag in Weld (In order of importance)

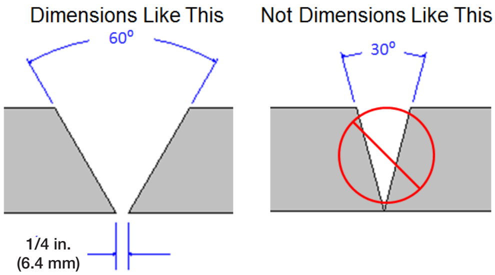
1. Increase weld joint opening
2. Keep arc ahead of the weld puddle by:
    a. Use drag angle of 20° to 30° (never use a push angle)
    b. Increase travel speed
    c. Decrease wire feed speed and voltage
3. Weld with vertical up progression instead of vertical down

Trapped Slag

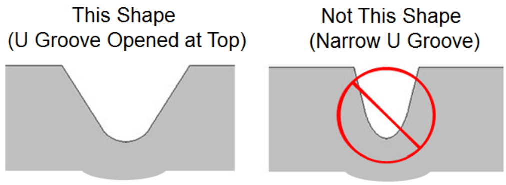
Slag inside the weld is a discontinuity and is often detected using ultrasonic testing (UT) or radiographic testing (RT) (aka x-ray) non-destructive testing (NDT). It can be a fairly common occurrence with flux cored electrodes and is almost always due to improper weld joint dimensions and/or operator technique.

Slag can become trapped inside the weld if there is not enough room in the joint for the slag to fully clear the puddle (i.e. float to the surface) before the weld metal solidifies. This often occurs when welding in a tight narrow joint. With groove welds for example, ensure that the root opening and included angle are wide enough to allow room for the slag to clear. This joint design is also necessary to properly manage the arc and ensure the proper root pass depth to width ratio (~1:1). Proper joint dimensions are critical with both the original joint preparation and when arc gouging the back side of a groove weld to sound weld metal and then welding from that side. Make sure the gouged out joint is not a deep "U" groove, but rather is opened up at the top of joint in more of a "V" pattern. The pictures below illustrate examples only of good and bad joint preparations.

Recommended Joint Prep to Avoid Trapping Slag in Welds



When Arc Gouging to Sound Weld Metal, Recommended Joint Shape to Avoid Trapping Slag in Succeeding Welds



OPERATING GUIDE

TROUBLESHOOTING INNERSHIELD WELD PROBLEMS

Trapped Slag (Cont'd)
Slag can also get trapped inside the weld if allowed to run ahead of the puddle. The operator needs to keep the arc focused in the joint just ahead of the puddle. Use a drag travel angle to keep the slag behind the arc, with the arc force helping to push it back. Also use a travel speed that is fast enough to stay ahead of the puddle. If too slow, then the arc may ride on top of the puddle, allowing the molten weld metal and molten slag to run around and in front of the arc. Some of the slag then rolls under the puddle and gets trapped inside the bead as it solidifies. In addition, use a controllable wire feed speed. Don't try to "hog in" a large weld bead in the joint by running excessive WFSs and slow travel speeds. This will increase the chances of trapping slag in the weld. If welding in the vertical position, use a vertical up progression, such that gravity helps hold back the slag. With vertical down progression, gravity is always pulling the slag into the arc.

HYDROGEN CONTROL

Hydrogen Control
Minimizing the amount of hydrogen that diffuses into (and over time back out of) weld metal can help make it more resistant to cracking. This is particularly true with higher strength, low alloy steels, hard to weld steels, thicker plates, highly restrained joints, etc. Sources of hydrogen can come from surface contaminants on the steel, the atmosphere and particularly from the welding electrode.

The AWS filler metal specifications for flux-cored electrodes state that "Flux-cored arc welding is generally considered to be a low hydrogen welding process" (section A8.2.4). Further, these specifications have optional supplemental designators for use with the various electrodes' classification numbers which indicate the maximum diffusible hydrogen levels of 4, 8 and 16 milliliters (ml) per every 100 grams (g) of deposited weld metal. In general, Innershield electrodes will produce weld deposits which have a maximum of 16 ml of diffusible hydrogen per 100 g of weld metal.

Innershield products, like other types of electrodes which produce deposits low in diffusible hydrogen, must be protected from exposure to the atmosphere in order to;
(a) Maintain hydrogen levels as low as possible
(b) Prevent porosity during welding
(c) Prevent rusting of the product

HYDROGEN CONTROL

More Restrictive Hydrogen Control
Some welding applications require more restrictive hydrogen control in the electrode, such that they must have a maximum diffusible hydrogen rating of "H8". Some Innershield products have been designed and manufactured to produce weld deposits meeting these more stringent diffusible hydrogen requirements. They are sometimes designated with an "-H" at the end of the product's name. These electrodes will remain relatively dry under recommended storage conditions in their original, unopened package or container.

For applications in which the weld metal hydrogen must be controlled (usually H8 or lower), or where shipping and storage conditions are not controlled or unknown, only hermetically sealed packaging is recommended. Many Innershield electrodes are available in hermetically sealed packages, such as pails and vacuum foil bags. Once the package is opened, the wire should be used as soon as practicable.

The following Innershield electrodes are available in hermetically sealed packages.

- Innershield NR-203 Ni C Plus-H
- Innershield NR-207
- Innershield NR-208-H
- Pipeliner NR-207+
- Pipeliner NR-208-P
- Pipeliner NR-208-XP
- Innershield NR-232
- Innershield NR-233
- Innershield NR-305
- Innershield NR-311 Ni
- Innershield NR-440Ni2
- Innershield NR-555
- Innershield NR-FAB-70

Hermetically Sealed Innershield Packaging

STORING INNERSHIELD ELECTRODES

Unopened Packaging

The following storage conditions are recommended for Innershield electrodes in their original, unopened and undamaged packages. First, the electrodes should be protected from weather (i.e. rain, snow, etc.) and other adverse conditions. They should be stored in an environment which maintains conditions above the dew point temperature for a given relative humidity (up to approximately 70%) in order to prevent moisture condensation on the wire. Minimizing temperature variation will also help to protect the electrode from moisture condensation.

For best results, Innershield electrodes should be consumed as soon as practical. It is advisable to maintain turnover in inventory to ensure the product is as close to the manufactured condition as possible. However, properly stored electrodes may be kept up to three years from the date of manufacture. Since actual storage conditions vary widely across geographical regions and from one customer to another, it is not possible to be more specific. For packages that are not hermetically sealed (i.e. air tight), a shorter storage time is advisable under sustained severe humidity conditions. But it is not possible to estimate this shorter time. Consult your Lincoln Electric distributor or sales representative if there is a question as to when the electrode was made.

Opened Packaging

Once the electrode packaging is opened, Innershield electrodes can become contaminated by atmospheric moisture. Care has been taken in the design of these products to ensure that they are resistant to moisture pick-up. However, condensation of moisture from the atmosphere onto the surface of the electrode can be sufficient to degrade the product. Innershield electrodes will show evidence of high moisture levels in the form of gas marks on the weld surface, higher spatter levels and porosity. Any rusty electrodes should be discarded.

The following minimum precautions should be taken to safeguard the product after opening the original package. Electrodes should be completely used within approximately one week after opening the original package. Opened electrodes should not be exposed to damp conditions or extremes in temperature and/or humidity where surface condensation can occur. Electrodes mounted on wire feeders should be protected against condensation. Ideally it is recommended that the electrode be removed from the wire feeder and placed in poly bags (four mil minimum thickness) when not in use.

Conditioning Wire

After exposure, hydrogen levels can be reduced by conditioning (i.e. baking) the wire. Wires may be conditioned at a temperature of 212° F ± 25° F (100° C ± 4° C) for a period of 6 to 12 hours, cooled and then stored in a sealed poly bag (4 mil minimum thickness) or equivalent. Wire on plastic spools should not be heated to temperatures in excess of 150° F (65° C).

ADDITIONAL INSTRUCTIONS
Innershield NR-211-MP and NR-212

While there is a full portfolio of electrodes in the Innershield product line, some are very popular and widely used, while others are for smaller, niche applications. This section will provide additional instructions on some of our more popular electrodes, as well as those requiring more advanced operator techniques.

Innershield NR-211-MP
Innershield NR-211-MP is one of the most popular Innershield electrodes.

Electrode Highlights:

- **Sheet Metal Applications:** It is intended for use on sheet metal (i.e. gauge steel) and thin plate, up to a maximum thickness of:
  - 5/16 in. (7.9 mm) with 0.030, 0.035 and 0.045 in. (0.8, 0.9, 1.1 mm) diameter wires.
  - 1/2 in. (12.7 mm) with 0.068, 5/64 and 3/32 in. (1.7, 2.0, 2.4 mm) diameter wires.
- **Great Operator Appeal:** It has a very smooth, spray arc like transfer for easy operation, with minimal spatter. Slag is easy to remove. It has the best appeal of all the Innershield electrodes.
- **All Position Welding Capability (except 3/32 in. (2.4 mm) diameter):** Can be used for flat, horizontal, vertical down and overhead welding. While vertical up welding is also possible, it may be more difficult. Per the AWS flux-cored filler metal specification, the slag system for this classification of electrode ("T-11") may be too light to consistently support a larger molten weld puddle with vertical up progression and spillage could occur. While Innershield NR-211-MP's particular slag system is fairly robust, success with vertical up welding will still be more dependent on individual operator skill than with the other welding positions.
- **Galvanized Sheet Metal:** Good resistance to porosity on galvanized sheet metal and other coated steels.

Welding Techniques:

- **Flat, Horizontal, Overhead:** Use a 10° to 20° drag travel angle with a straight progression (i.e. stringer beads).
- **Vertical Down:** Make stringer beads using a 10° drag travel angle. Make sure the arc stays ahead of the slag. A slight wiggle of the arc can also be used to flatten out the bead. Use one volt lower settings for vertical down and overhead welding.

WARNING: Because the operator appeal is very good with Innershield NR-211-MP, it is sometimes misused for the wrong applications. **DO NOT use it for welding on steel thicker than 1/2 in. (12.7 mm) or 5/16 in. (7.9 mm), depending on diameter.** Do not exceed steel plate thickness limits. It is intended for **sheet metal** applications. Note also that it has no specified minimum Charpy V-Notch toughness properties.

ADDITIONAL INSTRUCTIONS Innershield NR-211-MP and NR-212

Innershield NR-212
Innershield NR-212 operates similar to NR-211-MP.

Electrode Highlights:
- **Sheet Metal Applications:** Intended for use on thinner plate, up to a maximum thickness of 3/4 in. (19 mm) for all diameters.
- **Great Operator Appeal:** Smooth, spray arc like transfer for easy operation - similar to Innershield NR-211-MP.
- **All Position Welding Capability**

Welding Techniques:
- Same as Innershield NR-211-MP

WARNING: DO NOT use on steel thicker than 3/4 in. (19 mm).

ADDITIONAL INSTRUCTIONS Innershield NR-232 and NR-233

Innershield NR-232 and NR-233 are also some of the most popular and widely used Innershield electrodes.

Electrodes Highlights:
- **High Productivity:** Capable of producing high deposition rates for out-of-position welding. The heavy "casting" type fast freezing slag system allows you to carry a larger molten weld puddle against gravity (i.e. vertical up and overhead positions), resulting in the highest deposition rates possible with out-of-position welding [up to ~ 6.5 lbs/hr (2.9 kg/hr)]. These rates are more than double that of a 1/8 in. (3.2 mm) E7018 stick electrode.
- **Excellent Bead Appearance:** Weld beads are flat and smooth.
- **Great Slag Removal:** Slag is typically self-pealing, falling off by itself or with just a light scrap of chipping hammer.
- **Good Mechanical Properties:** Both electrodes produce excellent mechanical properties, including good Charpy V-Notch toughness (within the specifications of an E71T-8 classification).
- **Versatile:** Designed for single or multiple pass all position welding on 3/16 in. (5 mm) and thicker steel.
- **Structural Steel Welding:** All these key highlights make Innershield NR-232 (primarily) and Innershield NR-233 the preferred electrodes for structural steel erection/field welding.

Electrode Differences:
Innershield NR-232 and Innershield NR-233 both meet an E71T-8 classification and are both used for various structural steel welding applications. Innershield NR-232 is the older product and has a more established market base. Innershield NR-233 is a newer formulation and considered more user friendly for welders new to this type of electrode. The following table highlights the key differences between the two electrodes.

ADDITIONAL INSTRUCTIONS
Innershield NR-232 and NR-233

Electrode	Manufacturing Process	Arc Characteristics	Managing Slag	Bead Profile	Gun Tube Style
NR-232	Green rod	Harsher, more forceful	Slightly harder	Flatter	Reverse bend
NR-233	Strip	Softer	Slightly easier	More convex	No reverse bend

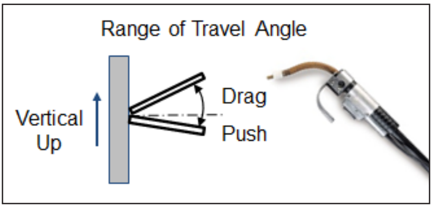
Innershield NR-232 Diameters:
Innershield NR-232 is available in three diameters, with each size best for different applications.

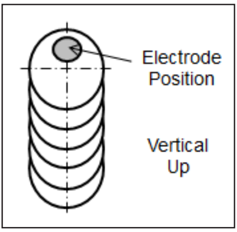
» 0.068 in. (1.7 mm): Better for weaving fillet and groove welds, easiest size to handle.
» 0.072 in. (1.8 mm): Best for vertical up stringers on fillets and grooves, best slag removal and produces the flattest weld face.
» 5/64 in. (2.0 mm): Operator qualification test certifies welder for use on all diameters. Along with the 0.068 in. diameter wire, handles plate contaminations (oil, rust, primer, etc.) better than the 0.072 in. diameter wire.

Innershield NR-233 Diameters:
Innershield NR-233 is available in three diameters also, 1/16 in. (1.6 mm), 0.072 in. (1.8 mm) and 5/64 in. (2.0 mm). All three sizes are operationally the same. Note however that the 1/16 in. (1.6 mm) size is uniquely smaller than other sizes for these wires and is easier to manage the puddle and slag system. 1/16 in. (1.6 mm) Innershield NR-233 is the recommended wire and size for welders who have little to no experience with these two types of high deposition, heavy slag system Innershield electrodes.

Welding Techniques:
CONTROL OF THE SLAG AND THE MOLTEN PUDDLE ARE THE KEYS TO SUCCESSFUL OPERATION OF THESE ELECTRODES.

» **Flat, Horizontal, Overhead:** Use a 10° to 20° drag travel angle with a straight progression (i.e. stringer beads). Always watch the slag. Do not let slag run ahead of the puddle.
» **Vertical Down:** Not recommended. Do not weld vertical down.
» **Vertical Up:**
  » For straight progression stringer beads, give the electrode a slight "wiggle" or shake to help flatten out the bead.
  » Use the least drag travel angle to keep the slag back from the arc. With a drag angle, the wire is pointing down into the puddle as you travel up. Faster travel speeds may require a push angle.





ADDITIONAL INSTRUCTIONS
Innershield NR-232 and NR-233

Vertical Up (Cont'd):

- It may be beneficial to use a slight drag angle at bottom of joint, and then slowly transition to a slight push angle as the base metal gets hotter. The drag angle at the start helps hold the slag back. Then as it heats up a push angle helps direct heat away from the slag shelf, allowing it to continue following closely below the electrode.
- Keep arc focused on front half of puddle. Progress upward with the puddle. If travel is too fast, the arc gouges into the plate and the bead can spill out.
- When weaving, use a side to side weave pattern. Focus arc on the upper half of the exposed puddle. Progress upward at a slight angle across the weld face.
- Pause at the edges of weld only long enough to achieve good wash-in with the plate. Excessive pausing will cause lumpy edges.
- Maximum weave width is 3/4 in. (20 mm). After which use split layers with each bead 1/2 in. (13 mm) to 3/4 in. (20 mm) wide.
- Always watch the slag line behind the puddle. Locate the arc in the puddle so that the slag freezes uniformly and only behind the puddle. Do not allow it to run ahead of the puddle. Maintain an even line of slag. If the slag line drops too much to one side or splits in the middle, it can collapse and cause the weld metal to spill out.
- With proper travel speed and slag management, you have good clarity of the puddle. When travel speed is too slow or voltage too high, puddle visibility can become cloudy.
- Adjust CTWD as necessary. A shorter CTWD will result in a hotter arc to keep the slag from freezing too soon. With proper CTWD [1 in. (25 mm)] the arc has a crisp, uniform hiss and a hotter puddle with good wetting action and uniform weld bead edges. If CTWD is too long, the slag cools too quickly, causing a round humpy bead. For open gaps, the CTWD may need to be up to 1-1/2 in. (38 mm).
- For restarts, use a slightly longer CTWD to establish the arc and slag shelf then reduce the CTWD back to proper length.

Training Video and DVD:
Go to our website ("Support" – "Resource Center" – "Lincoln Electric TV") to see the video **"Welding with NR-232 and NR-233"** with instructions on proper operation and welding techniques. https://www.youtube.com/watch?v=NGAiVOGkS-Y.

Resource Center
Lincoln Electric TV
Learn more about Lincoln Electric equipment, consumables and basic welding techniques with our hands-on training. Tricks and Tips videos on YouTube.

ADDITIONAL INSTRUCTIONS
Innershield NR-232 and NR-233

Weld Troubleshooting Guide

Innershield NR-232/NR-233 Weld Troubleshooting Guide	
Problem	**Possible Cause**
Poor arc action	1. Arc voltage too low for WFS (or vice versa) 2. CTWD too long 3. Arc blow condition 4. Wire feeding problems 5. WFS at low end of range
Irregular slag follow	1. Travel speed to fast 2. Weldment too hot 3. Excessive voltage 4. Mill scale or other surface contaminants 5. Wrong drag angle
Slag flooding arc	1. Arc voltage too low 2. Travel speed too low 3. WFS too slow for weld size being made 4. Wrong drag angle for travel speed 5. Arc blow condition
Poor slag removal	1. Poor bead shape 2. Slag flooding arc 3. Excessively hot weldment
Puddle spillage (V.U. and overhead) from slag separation (i.e. islanding)	1. Excessively hot weldment 2. Travel speed too fast 3. CTWD too short 4. Excessive surface contaminants (changes slag melting and solidification temperature) 5. Arc blow condition
Poor bead shape or rough edges	1. Wrong procedure 2. Wrong WFS/voltage ration 3. Arc blow condition 4. Wrong drag angle 5. Travel speed too slow 6. Weave too narrow or to slow 7. Too large a bead for WFS 8. Excessive surface contaminants 9. Worn or wrong contact tip or gun tube
Porosity	1. Excessive surface contaminants 2. Heavy primer and paint (>1 mil.) 3. Excessively high voltage 4. Slag interference due to travel speed or wrong procedure

ADDITIONAL INSTRUCTIONS
Innershield NS-3M

Use Innershield NS-3M for high deposition/high producivity welding.

Electrode Highlights:

» **Very high productivity:** Capable of producing deposition rates up to an astounding 30 lb/hr (13.6 kg/hr) and even higher using an extended stickout technique and procedures. It is for use in the flat and horizontal positions only.

» **Minimal penetration:** Operates on DC+ polarity and produces welds with very shallow penetration, resulting in minimal admixture with the base metal.

» **Good for hard to weld steels:** Best resistance to cracking when welding on crack sensitive steels such as higher carbon and high sulfur steels. Resists porosity on rusty, oily and high sulfur plates.

» **Good operator appeal:** Smooth, stable, soft arc characteristics.

» **Good bead apprearance:** Produces welds with smooth and shiny bead appearance.

» **Good slag removal:** Easy slag removal, even in deep grooves.

» **General fabrication:** Ideal for welding on machinery bases, heavy equipment repair and other large weldments. Note that there are no specified minimum Charpy V-Notch toughness properties with Innershield NS-3M.

Welding Techniques:

» **Flat and horizontal:** Recommended CTWD varies from 2-1/4 to 3-3/4 in. (57 to 102 mm). When using these extended stickout distances, establishing the arc can be more difficult. Start the arc with a shorter visible stickout (VSO). Then when the arc is established, increase CTWD to desired length. The long distance from the contact tip to the work also allows the electrode to wander more than if a shorter CTWD is used. “Linc-Fill” extended wire attachments can be added to the Innershield guns to guide the electrode and provide the right VSO length.

ADDITIONAL INSTRUCTIONS
Innershield NR-203 Family and NR-555

Innershield NR-203MP, NR-203 Nickel (1%), NR-203 Ni C Plus-H and NR-555

The Innershield NR-203 family is NR-203MP, NR-203 Nickel (1%) and NR-203 Ni C Plus-H. Very similar is NR-555. These wires have all position welding capability with great mechanical properties.

Electrode Highlights:

- **Great mechanical properties:** Including excellent Charpy V-Notch toughness properties.
- **All position welding capability:** Can be used for single and multiple pass welding in the flat, horizontal, vertical up, vertical down and overhead positions.
- Pause at the edges of weld only long enough to achieve good wash-in with the plate. Excessive pausing will cause lumpy edges.
- **Weathering steel:** Use Innershield NR-203 Nickel (1%), NR-203Ni C Plus-H (~1.5% nickel) or NR-555 (~1.1% Ni) for color match and similar corrosion resistant properties when welding on ASTM A588 and other grades of weathering steels.
- **Higher strength:** Innershield NR-555 is rated 80 ksi min. tensile.
- **Typical applications:** Structural steel, bridges, offshore, shipbuilding, piping and other applications requiring all position welding with good notch toughness properties.

Differences from other "T-8" classified electrodes:

The Innershield NR-203 family of electrodes have the same popular base E71T-8 AWS classification as Innershield NR-232 and NR-233, as well as Innershield NR-207, NR-208-H, Pipeliner 207+ and Pipeliner 208-XP. All are rated for all position welding with the same minimum mechanical properties. However, the NR-203 family, plus NR-555, have a much different slag system than NR-232 and NR-233. While both types are fast freezing, the NR-203 family and NR-555 do not have a heavy, casting type slag. They are not capable of achieving the same type of out-of-position deposition rates as NR-232 and NR-233. However, with their lighter slag, they operate very well with vertical down progression, while NR-232 and NR-233 do not. In addition, with some additional alloy content, the NR-203 family and NR-555 produce welds with even better notch toughness than NR-232 and NR-233. The NR-207 and NR-208 pipe welding electrodes are more similar to the NR-203 family of electrodes in regards to slag system, operability and notch toughness. However, the pipe welding electrodes are designed for vertical down progression welding only, whereas the NR-203 family and NR-555 are truly used in all positions.

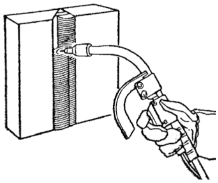
ADDITIONAL INSTRUCTIONS
Innershield NR-203 Family and NR-555

Welding Techniques:
The Innershield NR-203 electrode family and NR-555 tend to produce convex, ropy welds when using a stringer bead (i.e. straight progression) technique. Therefore, some manipulation or weaving of the puddle is needed to help flatten out the weld face.

» **Flat and horizontal:** Use a 10° to 20° drag travel angle with a straight progression (i.e. stringer beads). May use a very slight weave to help flatten out the face. Recommended max horizontal fillet weld is 5/16 in. (8 mm) leg size. Multiple pass welds use a 5/16 in. (8 mm) first pass, at 6 to 7 in/min (15 to 18 cm/min) travel speed.

» **Vertical Down:** Make stringer beads using a 10° drag travel angle. Make sure the arc stays ahead of the slag. A slight wiggle of the arc can also be used to flatten out the bead. Maintain proper CTWD to avoid porosity.

» **Vertical Up:**
T-Joint - Use a slight weave. Single pass fillet weld weave technique is the same as for overhead welds. For 1/4 in. (6.4 mm) fillets, use a slight weave. For 5/16 in. (8 mm) fillets, weave 1/2 the electrode diameter on each side. Pause at the edges of weld only long enough to achieve good wash-in with the plate. Excessive pausing will cause lumpy edges. On multiple pass welds, after the first pass, use almost straight progression with only a slight weave. The first pass should be a 1/4 to 5/16 in (6.4 to 8 mm) fillet, at 4 to 5 in/min (10 to 13 cm/min) travel speed.

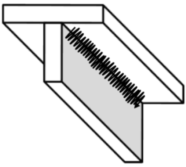


Butt Joint - Multiple pass technique is a straight side to side weave. Focus arc on the upper half of the exposed puddle. Progress upward at a slight angle across the weld face. Pause at the edges of weld only long enough to achieve good wash-in with the plate. Excessive pausing will cause lumpy edges. On large multiple pass welds, the pass thickness should not exceed 3/16 in. (4.8 mm). Maximum weave width is 1 in. (25 mm). After which use split layers with each bead a maximum of 3/4 in. (20 mm) wide. For cap passes, reduce WFS to improve puddle control and bead appearance.

Open Root Butt Joint - The root pass uses a longer CTWD [1-3/4 in. (45 mm) maximum], to cool puddle and improve control in the open gap. Use a slight half-moon motion, placing the electrode just high enough on the puddle to ensure complete penetration. If electrode position is too high on the puddle, it will dive through the gap. The puddle will then spill out or some imperfection will occur. If electrode position is too low on the puddle, full root penetration will not be achieved. With proper technique, the back bead will be flat to slightly concave.

ADDITIONAL INSTRUCTIONS
Innershield NR-203 Family and NR-555

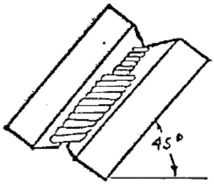
- **Overhead:**
  T-Joint - Use a slight weave. Techniques are the same as for vertical up T-joints (see instructions above). On multiple pass welds, use almost straight progression with only a slight weave. Allow the metal to wash up rather than down for best bead shape.

  Butt Joint - Use a slight weave. Techniques are the same as for vertical up butt joints (see instructions above).
  Open Root Butt Joint - Use a half moon weave. Techniques are the same as for vertical up open root butt joints (see instructions above). 5/8 in. (16 mm) and up groove welds use a wider weave and put in larger root pass to insure good tie-in and prevent cracking.
- **Pipe Welding:**
  Horizontal Butt Joint (2G) - Multiple pass technique is a series of straight stringer beads, with electrode on the upper half of exposed puddle. A very slight weave motion may be used. The root pass uses a longer CTWD [1-3/4 in. (45 mm) maximum], to cool puddle and improve control in the open gap. Use a slight half-moon weaving motion. 3/4 in. (20 mm) and larger butt joints use a wider weave and put in a larger root pass in order to insure good tie-in and prevent cracking.
  Vertical Up Butt Joint (5G) (includes overhead, vertical and flat) - Multiple pass technique is a straight side to side weave pattern, with electrode on the upper half of exposed puddle. Movement should be at a slight angle across the puddle. The weave direction is nearly perpendicular to the joint. Pause at the edges of weld only long enough to achieve good wash-in with the plate. Excessive pausing will cause lumpy edges. The root pass uses a longer CTWD [1-3/4 in. (45 mm) maximum], to cool puddle and improve control in the open gap. Use a slight half-moon motion. 3/4 in. (20 mm) and larger butt joints use a wider weave and put in a larger root pass in order to insure good tie-in and prevent cracking. Each fill pass thickness should not exceed 3/16 in. (4.8 mm). Do not weave wider than 1 in. (25 mm). Fill passes should use a split weave technique after that. Reduce WFS on cap passes to improve puddle control and bead appearance. For potentially improved Charpy V-Notch results, make fill passes smaller. In general, notch toughness and CTOD values improve as the number of passes to fill the joint are increased and/or interpass temperature is increased up to 500° F (260° C).

ADDITIONAL INSTRUCTIONS
Innershield NR-203 Family and NR-555

» **Pipe Welding (Cont'd):**
Vertical Up Butt Joint (6G) - All above butt joint techniques are used on 6G welding with the exception of weaving motion. With a 6G orientation, weave direction should always be parallel to the ground (horizontal), regardless of the puddle location around the pipe. Horizontal weaves give good edge control and uniform layer buildup.



A vertical up and vertical down motion results from weaving across the joint. This can produce a lumpy bead, slag entrapment and possible porosity.
Vertical Down Butt Joint (5G) - Root pass is made with vertical up progression. Using a vertical down progression for the fill and cap passes increases the cushion for meeting notch toughness and CTOD test requirements, but decreases the cushion for avoiding trapping slag and porosity. Due to the low heat input of vertical down welding, heat affected zone (HAZ) hardness may be high and should be checked to see if they meet the requirements of the job. Make stringer beads using a 15° drag to 5° push travel angle, as position on the pipe joint changes. Make sure the arc stays ahead of the slag. A slight wiggle of the arc can also be used to flatten out the bead. Maintain proper CTWD to avoid porosity. Edge wetting on cap passes can be improved by first removing mill scale from the pipe walls next to joint with a grinder.

» **T-Y-K Connections:** Follow the Innershield NR-440Ni2 Welding Techniques on T-Y-K connections.

ADDITIONAL INSTRUCTIONS
Innershield NR-440Ni2

Innershield NR-440Ni2 is a best in class electrode primarily for use in the offshore industry on T-Y-K connections. Operationally it is most similar to the NR-203 family.

Electrode Highlights:

» **Excellent Charpy V-Notch toughness:** Meets ABS "4YSA" and AWS "J" classifications. Best in class compared to comparable competitive electrodes (see graphs below).

» **Low diffusible hydrogen levels:** Meets H8 diffusible hydrogen requirements over a range of humidity levels.

» **All position welding:** Has both vertical up and vertical down welding capability.

» **Good offshore weldability:** Designed to provide optimal weldability in narrow T-Y-K tubular connections and poor fit up conditions.

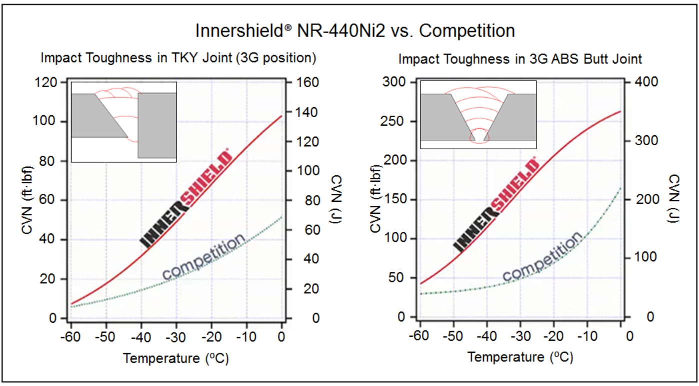
» **ProTech® packaging:** Hermetically sealed packaging for moisture resistance.

» **Q2 lot certification:** Certificate showing actual deposit chemistry and mechanical properties per lot available online.

ADDITIONAL INSTRUCTIONS
Innershield NR-440Ni2

Electrode Highlights (Cont'd):

» **Electrode classification:** A "T-8" low alloy electrode. It most closely resembles the NR-203 family of electrodes in regards to slag system and operability.



Offshore Welding and T-Y-K Connections:

Innershield NR-440Ni2 is primarily intended for use in offshore welding applications (i.e. offshore oil platforms). In particular, the electrode is used to weld on carbon and some low alloy steels, used in the fabrication of the mostly submerged support towers, called the "jacket", which supports the oil platform above the water. It is generally constructed from heavy wall pipe of various diameters, which come together in a series of T-Y-K tubular connections (aka "TKY" connections).

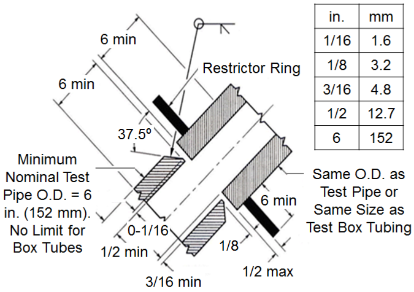
ADDITIONAL INSTRUCTIONS
Innershield NR-440Ni2

Welding Techniques:

6GR Joint Configuration

Welders typically practice and take a welder qualification test on a “6GR” pipe coupon, which best simulates the TKY connection welding conditions on an offshore jacket. A restrictor ring is tacked on one side of the joint to simulate the wall of the main tubular member. Note that the outside of the two pipes are flush with each other and that the pipe with the square edge has at least 1/4 in. (6 mm) larger wall thickness than the beveled pipe.

Innershield NR-440Ni2 tends to produce a convex, ropy weld when using a stringer bead (i.e. straight progression) technique. Therefore, some manipulation or weaving of the puddle is needed to help flatten out the weld face. Operationally, it is very similar to the Innershield NR-203 family of electrodes.



in.	mm
1/16	1.6
1/8	3.2
3/16	4.8
1/2	12.7
6	152

Root Pass:

- Use a vertical up progression.
- The root pass uses almost a straight progression with only a slight weave (i.e. a “U” motion, or forward or backward “J” motion). Focus the arc on the heavier wall, but frequently and quickly wash the puddle back over to the beveled side of the joint to bridge the root opening.
- Use a drag angle of 10°- 20°.
- CTWD can vary from 5/8 to 1-1/4 in. (16 to 32 mm). You have to constantly adjust CTWD on the root pass. Note that you can “heat up” or “cool down” the puddle by using a shorter or longer CTWD, which has the effect of increasing or decreasing the current level. This in turn has the effect of increasing or decreasing the degree of penetration.
- The electrode should be positioned on the leading half of the puddle, but not on the leading edge of puddle. If too high, it will blow through the gap, leading to puddle loss. If too low, lack of penetration and incomplete back bead occurs.
- Even with proper technique, there may be trapped slag in the toes of the root pass. With a power grinder, grind out the slag in the toes, as well as grind the face of the weld so that it is relatively flat. The first fill pass (aka the “hot” pass) will burn out some of the slag remaining in the joint. However, the majority of it must be first removed with a grinder.

ADDITIONAL INSTRUCTIONS
Innershield NR-440Ni2

Fill Passes:

- Use a vertical up progression.
- The fill passes are made with a straight side to side weave technique, staying on the upper half of the exposed puddle.
- There should be very little hesitation at the edges of the puddle for good wash-in and flat bead face. The weld metal tends to flow to the edges of joint and too much hesitation at edges will push metal to center, causing convex beads. However, too little of hesitation at the edges results in poor wash-in.
- Pass thicknesses should not exceed about 3/16 in. (5 mm).
- Maximum weave width is 3/4 in. (19 mm), after which layers should be split weaves with each bead 1/2 to 3/4 in. (13 – 19 mm) wide.
- To achieve the best CVN toughness values, weld beads should be as small as possible. Again, there will be a natural tendency by welders to do the opposite, because the wider and larger the weld beads, the better they look and the easier the slag is to remove. Be diligent in making sure that after just a few layers the fill passes are split and made as small as possible.
- In 6G position, weave parallel to the ground to produce uniform beads with good wash-in at edges.
- The last cap passes should bring the weld metal flush with the top of the joint. The joint should be completely filled in with weld metal, but avoid over welding the last cap passes.
- Even with proper technique, there will be trapped slag in the toes of the fill passes, particularly the initial ones deep in the groove. With a power grinder, grind out the slag in the toes, as well as grind the face of the weld so that it is relatively flat.
- As you come out of the joint with the fill passes and they become wider, the slag will be less likely to be trapped in the toes and will be easier to remove. Eventually, each fill pass can be thoroughly cleaned with just a power wire wheel.

Cap Passes:

- Grind the last fill passes so that there is a smooth, flat surface in the weld joint on which to weld the cap passes. Think of the cap passes as just a thin blanket laid over the top of the joint. Any bumps, voids, etc. from the last fill passes will show through in the cap passes (unless a clean, flat foundation is made first).
- Using a thin cutting wheel, grind a small line along the edge of one side of joint to provide a guide or path to follow when making the first cover pass. You can also use soap stone to make the guideline. You can then use the previous weld bead as your guide when making the next cover pass, or continue marking or grinding a small guideline next to each succeeding weld pass.
- Use a vertical down progression. Cap passes are typically welded vertical down to ensure a flat bead appearance and good wash in between beads and the pipe.
- Use a straight stringer to slight side to side weave technique, maintaining the weave width at less than 5/16 in. (8 mm) wide and weaving (oscillating) quickly across the weld face.

ADDITIONAL INSTRUCTIONS
Innershield NR-440Ni2

- Adjust travel speed to ensure that the slag line follows at an optimal distance behind the arc.
- Use a shorter CTWD for better arc stability.
- A slight drag angle of about 10° is used to provide enough arc force to maintain puddle control.
- Check the transition between cap passes and between outside cap passes and the pipe with a coin (e.g. U.S. quarter) and paper clip. Hold the coin on end on the ridge between passes. If you can fit the end of the paper clip through the gap, the ridge is too deep. Grind smooth and redo caps.

LINCOLN ELECTRIC WELDING SCHOOL

Need Welding Training?
The Lincoln Electric Company operates one of the oldest and most prestigious arc welding schools in the United States at its corporate headquarters in Cleveland, Ohio. Since 1917, Lincoln Electric's Bill West Memorial Welding School has instructed over 100,000 men and women in the various methods and techniques of safety and arc welding processes. The school is listed by the Ohio State Board of School and College Registration, certificate # 71-02-059T.

Lincoln Electric's Welding School offers a variety of classes, from a six week "Basic" course to an advanced fifteen week "Comprehensive" course, as well as several one week classes on specific welding processes, certification or customized programs. Classes run from 8:00 a.m. – 2:30 p.m. daily, five days per week and fifty weeks per year. Students spend about 20% of their time in the classroom and 80% in the booth learning to weld. Instructor to student ratio is kept small to provide plenty of individual help. A large supply of steel plate is provided so students spend all their time learning to weld, not cutting and preparing practice coupons. For more information, go to **www.lincolnelectric.com/en-us/education-center/welding-school/Pages/welding-school.aspx**

Flux-cored Welding Course

Take a one week class in flux-cored welding (also part of the 15 week Comprehensive program). The course is designed to instruct welders in welding safety and the Flux-Cored Arc Welding process for both the self-shielded (Innershield) and gas-shielded (UltraCore and Outershield) sub-processes. It involves approximately 30 hours of booth instruction, lecture and practice. Course content includes:

» Learn the fundamentals of the FCAW process.
» Weld on 10 gauge (3.5 mm) through 1 in. (25 mm) thick steel in all welding positions.
» Use a variety of electrodes, wire feeders and power sources.
» Practice on typical joint designs used in construction and shipbuildiong, making fillet and groove welds.
» Take a weld test at end of course.

One week courses are also offered to companies and/or individuals who want to practice flux-cored welding techniques for passing an operator qualification test(1) or procedure qualification test(1). This course also gives the proper application skills to an instructor for inplant training with Innershield and/or UltraCore electrodes.

On-site Training

The Lincoln Electric Welding School can also meet your needs for customized Innershield (and other processes) training at your particular location. Contact your local Lincoln Electric Technical Sales Representative or the school manager at 216-383-2259 for details.

(1) Actual testing done by an independent testing facility or at customer's location.

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