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- An interruption of the typical structure of a material, such as
 - a lack of homogeneity in its mechanical, metallurgical, or physical characteristics.
- A discontinuity is not necessarily a defect.

Defect

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- a flaw or flaws
- by nature or accumulated effect renders a part or product unable to meet minimum applicable acceptance standards or specifications.
- the term designates rejectability.

Weld Joint Discontinuities

- Misalignment (hi-lo)
- Undercut
- Underfill
- Concavity or Convexity
- Excessive reinforcement
- Improper reinforcement
- Overlap
- Burn-through
- Incomplete or Insufficient
 Penetration
- Incomplete Fusion
- Surface irregularity
 - Overlap
- Arc Strikes

Inclusions

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- Slag
- Wagontracks
- Tungsten
- Spatter
- Arc Craters
- Cracks
 - Longitudinal
 - Transverse
 - Crater
 - Throat
 - Toe
 - Root
 - Under-bead and Heataffected zone
 - Hot
 - Cold or delayed

- Base Metal Discontinuities
 - Laminations and Delaminations
 - Lamellar tearing
 - Laps and Seams
- Porosity

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- Uniformly Scattered
- Cluster
- Linear
- Piping
- HAZ microstructure alteration
- Size or dimensions

Discontinuity Classifications

- Design Related
- Weld Process related
- Metallurgical

Design Related

- Incorrect detail
- Wrong joint application
- Undesirable change in cross section
- These are *Engineering Problems*
- Typically beyond the realm of <u>INSPECTOR</u> knowledge unless a specific Code applies

Engineering Problems?

- Engineers can make mistakes?
 - Lack familiarity with welding
 - Misinterpret design intent
 - Applied stresses
 - Fabrication sequence
 - Weld process capabilities
 - TYPICALLY show up in first-part manufacture

or

- After service failure
- The knowledgeable INSPECTOR may find these problems and needs to work with engineering to resolve

Weld Process Related

'LOTS OF FAIR QUESTIONS HERE)

- Undercut
 - Groove melted in basemetal adjacent to weld edge and left unfilled
- Slag Inclusion
 - Nonmetallic solid entrapped in weld
- Porosity
 - Gas cavity trapped during solidification
- Overlap
 - Weld metal protrusion beyond toe, face or root
- Tungsten inclusion
 - Tungsten electrode particles entrapped in weld
- Melt-through
 - Condition where arc melts through weld root
- Spatter
 - Metal particles expelled during welding that do not become part of the weld.

- Backing piece left in place
 - Failure to remove backing
- Shrinkage voids
 - Cavities formed by shrinkage at solidification
- Oxide Inclusions
 - Un-melted surface oxide particles
- Lack of fusion (LOF)
 - Less than complete fusion
- Lack of Penetration
 - Less than the specified penetration
- Craters
 - Depressions at the termination of the weld bead
- Arc strikes
 - Localized re-melted or heat affected metal resulting from an errant arc
- Under fill
 - A depression of the weld below the intended profile

Metallurgical Discontinuities

- Cracks
 - Fracture type discontinuities characterized by a sharp tip and a high length to depth ratio
- Fissures
 - Small crack-like discontinuities with only slight separation of the fracture surfaces
- Fisheye
 - Discontinuity found on the fracture surface of a steel weld consisting of a small pore surrounded by a bright round area
- Segregation
 - non-uniform distribution or concentration of impurities or alloying elements during solidification
- Lamellar tearing
 - Cracking that occurs in the basemetal or heat affected zone of restrained weld joints

Misalignment (hi-lo)

- Definition: Amount a joint is out of alignment at the root
- **Cause:** Carelessness. Also due to joining different thicknesses (transition thickness)
- **Prevention:** Workmanship. Transition angles not to exceed 2.5 to 1.
- **Repair:** Grinding. Careful on surface finish and direction of grind marks. Inside of Pipe /Tube difficult.

Undercut

- **Definition:** A groove cut at the toe of the weld and left unfilled.
- **Cause:** High amperage, electrode angle, long arc length, rust



- **Prevention:** Set machine on scrap metal. Clean metal before welding.
- **Repair:** Weld with smaller electrode, sometimes must be low hydrogen with preheat. Sometimes must gouge first.

UNDERCUT



Undercut

(cont.....)

- Undercut typically has an allowable limit.
- Different codes and standards vary greatly in the allowable amount.
- Plate the lesser of 1/32" or 5% (typ.)

Insufficient Fill Definition:

- The weld surface is below the adjacent surfaces of the base metal
- Cause: Improper welding techniques
- Prevention: Apply proper welding techniques for the weld type and position. Use stripper beads before the cover pass.
- Repair: Simply weld to fill. May require preparation by grinding.

UNDERFILL





Insufficient Fill on the Root Side (suckback)

- Definition: The weld surface is below the adjacent surfaces of the base metal at the weld root.
- Cause: Typically improper joint preparation or excessive weld pool heat.
- Prevention: Correct cause. (see next slide) Repair: Backweld to fill. May require removal of weld section by grinding for access to the joint root.

Cause for Insufficient Fill at the Root

- Some liquids, like water or molten steel, try to cover as much surface area of whatever they are in contact with as possible.
- Welding a root pass too wide can also cause the bead to sag (overhead position).



Cause for Insufficient Fill at the Root

Ideally





Remove root pass by grinding

- Recreate the groove geometry as closely as possible.
- Use a saw or die grinder and 1/16 1/8" cut off wheel to recreate root opening.
 - Repairs sometimes require a smaller electrode.
- Open the groove angle. Be careful to leave the proper root face dimension.
- Feather the start and stop to blend smoothly into and out of the existing weld.





Excessive Concavity or Convexity

- Definition: Concavity or convexity of a fillet weld exceeding specified limits
- Cause: Amperage and travel speed
- Prevention: Observe proper parameters and techniques.
- Repair: Grind off or weld on. Must blend smoothly into the base metal.

Concavity



EXCESSIVE CONCAVITY





Convexity





Reinforcement

- The amount a groove weld extends beyond the surface of the plate
 - Excessive
 - Insufficient
 - Improper contour



Root Reinforcement

Excessive Reinforcement

- Definition: Specifically defined standard.
- Typically, Flush to 1/16" (pipe) or flush to 1/8" (plate or structural shapes).
- Cause: Travel speed too slow, amperage too low Prevention: Set amperage and travel speed on scrap plate.
- Repair: Remove excessive reinforcement and feather weld toes to a smooth transition to the base plate.

EXCESSIVE WELD REINFORCEMENT



Insufficient Reinforcement

- Definition: Specifically defined standard.
- Typically, None or up to 5% of metal thickness not to exceed 1/32" as long as the thickness is made up in the opposite reinforcement. Not applied to fillet welds.
- Cause: Open root reinforcement Too little filler metal will cause thinning of the filler metal. In OH position, too hot or too wide will cause drooping of the open root puddle.
- Prevention: Use proper welding technique. Use backing or consumable inserts. Use back weld or backing.
- Repair: Possibly simply increase the face reinforcement.
 If back-welding is not possible, must remove and re-weld.

Improper Weld Contour

- Definition: When the weld exhibits less than a 135° transition angle at the weld toe.
- Cause: Poor welding technique
- Prevention: Use proper techniques. A weave or whip motion can often eliminate the problem.
- Repair: The weld face must be feathered into the base plate.



UNACCEPTABLE WELD PROFILES



UNACCEPTABLE WELD PROFILES



Overlap

- Definition: When the face of the weld extends beyond the weld toe
- Cause: Improper welding technique. Typically, electrode angles and travel speed.
- Prevention: Overlap is a contour problem. Proper welding technique will prevent this problem.
- Repair: Overlap must be removed to blend smoothly into the base metal.
 - Be careful of deep grind marks that run transverse to the load.
 - Also be careful of fusion discontinuities hidden by grinding. Use NDT to be sure.

Overlap

•Overlap is measured with a square edge such as a 6" rule. No amount of overlap is typically allowed.

OVERLAP



Burn-through (non-standard)

- Definition: When an undesirable open hole has been completely melted through the base metal. The hole may or may not be left open with further processing.
- Cause: Excessive heat input.
- Prevention: Reduce heat input by increasing travel speed, use of a heat sink, or reduce welding parameters.
- Repair: Will be defined by standards. Filling may suffice. Otherwise, removal and re-welding may be required. Some standards may require special filler metal and/or PWHT.

Incomplete or Insufficient Penetration

- Definition: When the weld metal does not extend to the required depth into the joint root
- Cause: Low amperage, low preheat, tight root opening, fast travel speed, short arc length.
- Prevention: Correct the contributing factor(s).
- Repair: Back gouge and back weld or remove and reweld.

INCOMPLETE & EXCESSIVE PENETRATION



Incomplete Penetration of Double Weld

QuickTime[™] and a TIFF (Uncompressed) decompressor are needed to see this picture.