**API 577 - Welding Processes, Inspection, and Metallurgy**

1. Welding Processes
   1. General
   2. Shielded Metal Arc Welding (SMAW)
      1. **CC type**
      2. Electrode gives shield gas and adding alloys.
      3. Core wire becomes filler metal.

Pros

1. Simple, inexpensive,
2. Less sensitive to wind
3. Limited access can be used.
4. Less training required.

Cons

1. Deposition Rate slow, compared to GMAW
2. Slag to remove before next pass.
   1. Gas Tungsten Arc Welding (GTAW)
      1. **CC type**
      2. DCEN gives deeper penetration and faster.
      3. ACEP times give cathodic cleaning for non-ferrous metals such as Al and Mg.

Pros

1. High purity weld
2. Little post weld cleaning
3. Excellent control on root pass penetration
4. Filler or non-filler
5. Relatively defect- or contaminant- free root passes

Cons

1. Lower deposition rate
2. Low tolerances on contaminant base metal
3. Difficulty in shielding weld zone in drafty environment
4. Greater operator skill required than SMAW

* 1. Gas Metal Arc Welding (GMAW)
     1. **CV type –** so current can vary so transfer mode also can change. Short circuit, globular, spray or pulse.
        + 1. S – thin wall welding (fastest cooling)
          2. MS – good for non-exp
          3. Globular – Even small current, large heat input makes distortion and large residual stress. Deposition rate 6350 mm /min
          4. Spray – Not good for thinner than 6mm.
          5. Pulse – invented to mitigate above.
     2. External shielding gas
     3. Semi auto and automatic machine modes
     4. Depends on
        1. Type of current, magnitude
        2. Electrode diameter
        3. Electrode composition
        4. Electrode extension
        5. Shielding gas

Pros

1. Ferrous and non-ferrous
2. Deposition rate than GTAW, SMAW
3. Minimal post weld cleaning due to the absence of slag.

Cons

1. Costly
2. GMAW-S Lack of fusion chance more.
3. Must be protected from Air Draft
   1. Flux-Cored Arc Welding (FCAW)
      1. **DC CV type**
      2. Gas from flux inside tubular core. Additional Shield gas is optional.
      3. Semi auto

Pros

1. Metallurgical benefit from alloying elements from flux
2. Slag supports and shapes the weld bead, allowing slower cooling rate
3. Higher deposition rate compared to GTAW, SMAW
4. More tolerant to air current than GTAW

Cons

1. Complex, costly, less portable than SMAW
2. requires suitable exhaust equipment
3. Slag must be removed between weld passes. failure to remove slag from the weld cap or root can create sites for corrosion to initiate
4. Backing material required
5. not recommended for pressure-containing welds
   1. Submerged Arc Welding (SAW)
      1. **CV or CC type**
      2. Flux covered bare metal electrodes
      3. shielded by a blanket of granular flux, supplied through the welding nozzle from a hopper.
      4. Semi-auto, auto and machine welding
      5. Extensively used in shop pressure vessel fabrication and manufacturing pipe

Pros

1. Very high deposition rate
2. Repeatable high-quality welds for large weldments and repetitive short welds.

Cons

1. More costly and extensive equipment and less portable
2. Weld is not visible during process
3. High amperage of 100% duty cycle
4. Limited to shop application and flat position
   1. Stud Arc Welding (SW)
      1. **CC type**
      2. **DCEN** type
      3. Sheilding gas may be required or not.

Pros

1. high productivity rates compared to manually welding studs
2. all-position process

Cons

1. suitable for only carbon steel and low-alloy steels
2. fewer application
   1. Plasma Arc Welding (PAW)
      1. A variation of GTAW, electrode within the body
      2. Rarely used in Fabrication and Repair of pressure equipment
      3. Two types— **Transferred Arc and Non-Transferred Arc**
      4. Shielding gas

**Transferred Arc (Plasma Transferred Arc – PTA)**

Similar to GTAW, workpiece is a part of circuit. By constricting the arc, plasma or ionized gas is forced through nozzle with sound of speed. Collimated arc on small area of workpiece with temp 111000 °C.

**Non-Transferred Arc (Plasma Spray)**

Workpiece is not a part of circuit. Arc is between electrode and constricting nozzle.

Solely it is used for deposition of surface coating. It is not used for making strength weld.

Pros

1. high tolerance for misalignment in the arc
2. high welding rate
3. high penetrating capability (keyhole effect)
4. less distortion resulting from lower total heat input due to focused arc
5. the weld itself and the HAZ are narrower than in traditional GTAW due to the constricted arc

Cons

1. expensive equipment
2. larger torch than GTAW making access more difficult in narrow weld joints
3. focused arc requiring better control by the welder.
   1. Electrogas Welding (EGW)
      1. Similar to GMAW or similar to FCAW if used Flux Cored electrode
      2. Shielding gas can be supplied externally or flux-core gas
      3. Thickness 3/8 to 4 in (9 to 100 mm) like ship hulls, storage tanks and pressure vessels
      4. Min thickness of workpiece is 10 mm, electrode max thk is 20 mm.
      5. The height of the weld is limited only by the mechanism used to lift the welding head. In general, the height ranges from 4 in. to 50 ft (100 mm to 15 m).
      6. Low, Med CS, LAHS steels, SS can be used. QT steels can be used if additional heat input.

Pros

1. Welding usually one pass only
2. Very high deposition rate
3. Minimum distortion
4. Alloy elements additions

Cons

1. Massive, expensive equipment, guidance systems required
2. Low toughness
3. Lenthy setup time
4. Only vertical position
5. External shielding gas
6. Welding Materials
   1. General
   2. P-Number Assignment to Base Metals
      1. To reduce the number of welding procedure qualifications required
      2. group numbers within P-numbers are assigned based on impact test requirements
      3. QW-422 available for P-No, S-No and group number.
   3. F-Number Assignment to Filler Metals
   4. AWS Classification of Filler Metals
   5. A-Number
   6. Filler Metal Selection
   7. Consumable Storage and Handling
7. Welding Procedure
   1. General
   2. Welding Procedure Specification (WPS)
   3. Procedure Qualification Record (PQR)
   4. Reviewing the WPS and PQR
   5. Tube-to-Tubesheet Welding Procedures
8. Welder Qualification
   1. General
   2. Welders and Welding Operators
   3. Examination Failure of a Production Weld
   4. Retest for Qualification
   5. Expiration, Revocation, and Renewal of Welder or Welding Operator Qualification
   6. Welder Performance Qualification
   7. Reviewing a WPQ
   8. Limitations for Welder Qualifications
9. NDE
   1. Discontinuities/imperfections
   2. Materials Identification
   3. Visual Examination (VT)
   4. Magnetic Particle Examination (MT)
   5. Alternating Current Field Measurement
   6. Liquid Penetrant Examination (PT)
   7. Eddy Current Examination (ET)
   8. Radiographic Examination (RT)
   9. Ultrasonic Examination (UT)
   10. Hardness Testing
   11. Pressure and Leak Testing/Examination (LT)
10. Welding Inspection
    1. General
    2. Tasks Prior to Welding
    3. Tasks During Welding Operations
    4. Tasks Upon Completion of Welding
    5. Nonconformances and Defects
    6. NDE Examiner Certification
    7. Weld Inspection Data Recording
11. Metallurgy
    1. General
    2. Structure of Metals and Alloys
    3. Physical Properties
    4. Mechanical Properties
    5. Preheating
       1. to reduce the tendency for hydrogen-induced delayed cracking
    6. Heat Treatment
       * 1. To impart desirable mechanical properties to a steel that are appropriate
       1. Full Annealing
          1. Heating to above transformation temperature and cooling down in furnace
          2. Low hardness and high tougness and ductility values
       2. Normalizing
          1. Heating to above transofrmation temperature range and air-cool.
          2. Higher hardness and greater releative strength than full annealing.

* 1. Material Test Reports
  2. Weldability of Metals
  3. Weldability of High Alloys

1. Refinery and Petrochemical Plant Welding Issues
   1. General
   2. Hot Tapping and In-Service Welding
   3. Lack of Fusion With GMAW-S Welding Process
   4. Caustic Service
   5. Controlled Deposition Welding
2. Safety Precautions