Standards Available for the Plastics Welding and Fabrication Industry

Mike Troughton
TWI Ltd
Contents

• Standards on welding and fabrication of plastics
  – Tanks and vessels
  – Pipes
  – Lining membranes
• Standards on mechanical and non-destructive testing of plastics welds
• Standards on training and qualification of plastics welders
Contents

- Standards on welding and fabrication of plastics
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Welding and Fabrication of Plastics

Tanks and Vessels

• European Standards
  – CEN/TC249 (Plastics) /SC5 (Welding of thermoplastics materials)
    • WG1: Characteristic values
    • WG6: Welding machines for thermoplastics materials
    • WG8: Quality assessment for thermoplastics welds
  – Now CEN/TC249/WG16 (Thermoplastics welding)
  – CEN/TC266 (Thermoplastic static tanks)
WG1: Characteristic values

- **UK Principal Expert:**
  - Seamus Quinn (Chem Resist)

- **Standards:**
  - EN 1778:2000 Characteristic values for welded thermoplastic constructions – Determination of allowable stresses and moduli for design of thermoplastic equipment
  - EN 12943:2000 Filler materials for thermoplastics – Scope, designation, requirements, tests
Welding and Fabrication of Plastics

WG6: Welding machines

- **UK Principal Expert:**
  - Tom Hill (British Gas)
  - Mike Troughton (TWI)

- **Standards:**
  - EN 13705:2004 Welding of thermoplastics – Machines and equipment for hot gas welding (including extrusion welding)
Welding and Fabrication of Plastics

WG8: Quality assessment

- UK Principal Expert:
  - Mike Troughton (TWI)

- Standards:
  - EN 14728:2005 Imperfections in thermoplastic welds. Classification

- Under development
  - Quality levels for imperfections in thermoplastics welded joints
Welding and Fabrication of Plastics

CEN/TC266: Thermoplastic static tanks

- Standards:
  - EN 12573:2000 Welded static non-pressurized thermoplastic tanks
    - Part 1: General principles
    - Part 2: Calculation of vertical cylindrical tanks
    - Part 3: Design and calculation for single skin rectangular tanks
    - Part 4: Design and calculation of flanged joints
  - EN 13341:2005 Thermoplastics static tanks for above ground storage of domestic heating oils, kerosene and diesel fuels. Blow moulded polyethylene, rotationally moulded polyethylene and polyamide 6 by anionic polymerization tanks. Requirements and test methods
  - EN 13575:2004 Thermoplastics tanks made from blow or rotational moulded polyethylene. Tanks for the above ground storage of chemicals. Requirements and test methods
Welding and Fabrication of Plastics

Tanks and Vessels

• DVS Guidelines
  – DVS 2205 Design calculations for containers and apparatus made from thermoplastics
    • Part 1: Characteristic values
    • Part 2: Vertical round, non-pressurised tanks
    • Part 3: Welded joints
    • Part 4: Flanged joints
    • Part 5: Rectangular tanks
Welding and Fabrication of Plastics

Tanks and Vessels

- **DVS Guidelines**
  - **DVS 2207 Welding of thermoplastics**
    - Part 1: Heated tool welding
    - Part 3: Hot gas string-bead welding and hot gas welding with torch separate from filler rod
    - Part 4: Extrusion welding
  - **DVS 2227-1:2004 Welding of semi-finished products made of high-density polyethylene (PE-HD) for the sealing of concrete structures in the field of ground water protection and for corrosion protection**
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• **Standards on training and qualification of plastics welders**
Welding and Fabrication of Plastics

Pipes

- Large number of standards and specifications
- For polyethylene pipes:
  - European Standards
    - EN 1555 Plastics piping systems for the supply of gaseous fuels. Polyethylene (PE)
    - EN 12201 Plastics piping systems for water supply. Polyethylene (PE)
    - EN 12666 Plastics piping systems for non-pressure underground drainage and sewerage. Polyethylene (PE)
    - EN 13244 Plastic piping systems for buried and aboveground pressure systems for water for general purposes, drainage and sewerage. Polyethylene (PE)
Welding and Fabrication of Plastics

Pipes

- **International Standards**
  - ISO 4427 Polyethylene (PE) pipes for water supply
  - ISO 8085 Polyethylene fittings for use with polyethylene pipes for the supply of gaseous fuels. Metric series
  - ISO/TS 10839:2000 Polyethylene pipes and fittings for the supply of gaseous fuels – Code of practice for design, handling and installation
  - ISO 12176 Plastics pipes and fittings. Equipment for fusion jointing polyethylene systems
    - Part 1: Butt fusion
    - Part 2: Electrofusion
  - ISO 21307:2009 Plastics pipes and fittings. Butt fusion jointing procedures for polyethylene (PE) pipes and fittings used in the construction of gas and water distribution systems (*withdrawn 2010*)
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Welding and Fabrication of Plastics

Lining Membranes

• DVS guidelines
  – DVS 2225-1:1991 Joining of lining membranes made from polymeric materials (geomembranes) in geotechnical and hydraulic application – Welding, bonding by adhesives, vulcanising
  – DVS 2225-4:2006 Welding of sealing sheets made of polyethylene (PE) for the sealing of dumps and contaminated sites
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Mechanical and Non-destructive Testing of Plastics Welds

- European standards
- ISO standards
- Other standards/specifications
European standards

• CEN/TC249/SC5/WG2 (Testing of welded joints)
• UK Principal Expert: Mike Troughton (TWI)
• Mechanical tests:
  – EN 12814-1:2000 Bend test
  – EN 12814-2:2000 Tensile test
  – EN 12814-3:2000 Tensile creep test
  – EN 12814-4:2001 Peel test
  – EN 12814-5:2000 Macroscopic examination
  – EN 12814-6:2000 Low temperature tensile test
  – EN 12814-7:2002 Tensile test with waisted test specimen
  – EN 12814-8:2001 Requirements
Mechanical and Non-destructive Testing of Plastics Welds

- Bend test

\[ \alpha = \alpha_i - \alpha_f \]
\[ H = H_f - H_0 \]
Mechanical and Non-destructive Testing of Plastics Welds

- Tensile test

Type 1

Type 2
Mechanical and Non-destructive Testing of Plastics Welds

- Tensile creep test
Mechanical and Non-destructive Testing of Plastics Welds

- Peel test
  - T-peel

\[ L_i \quad L_c \]

\[ a_n \quad b \]

weld
Mechanical and Non-destructive Testing of Plastics Welds

- Peel test
  - Decohesion test
Mechanical and Non-destructive Testing of Plastics Welds

- Peel test
  - Crush test

Pipe

Coupler

Vice

> 5D_n

5mm

200mm

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Mechanical and Non-destructive Testing of Plastics Welds

- Low temperature tensile test

- Tensile test with waisted test specimen
• Requirements
  – Bend test

**Minimum bend angle for PE**

- **Heated tool**
- **Hot gas/ extrusion**

**Bend angle, degrees**

**Specimen thickness, mm**
### Mechanical and Non-destructive Testing of Plastics Welds

#### Requirements

<table>
<thead>
<tr>
<th>Process</th>
<th>Minimum short-term tensile welding factor, $f_s$</th>
<th>PE</th>
<th>PP</th>
<th>PVC-U</th>
<th>PVC-C</th>
<th>PVDF</th>
</tr>
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<tbody>
<tr>
<td>Heated Tool</td>
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<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
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<td>0.8</td>
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<tr>
<td>Extrusion</td>
<td></td>
<td>0.8</td>
<td>0.8</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Process</th>
<th>Minimum long-term tensile welding factor, $f_l$</th>
<th>PE</th>
<th>PP</th>
<th>PVC-U</th>
<th>PVC-C</th>
<th>PVDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heated Tool</td>
<td></td>
<td>0.8</td>
<td>0.8</td>
<td>0.6</td>
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<tr>
<td>Hot Gas</td>
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<td>0.4</td>
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<tr>
<td>Extrusion</td>
<td></td>
<td>0.6</td>
<td>0.6</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

ns = not specified
Mechanical and Non-destructive Testing of Plastics Welds

European standards

- CEN/TC249/SC5/WG2 (Testing of welded joints)
- Non-destructive tests:
  - EN 13100-1:2000 Visual examination
  - EN 13100-2:2004 X-ray radiographic testing
  - EN 13100-3:2004 Ultrasonic testing
  - prEN 13100-4 High voltage testing
Mechanical and Non-destructive Testing of Plastics Welds

ISO standards

- ISO 1167 Thermoplastics pipes, fittings and assemblies for the conveyance of fluids. Determination of the resistance to internal pressure
- ISO 13953: 2001 Polyethylene (PE) pipes and fittings. Determination of the tensile strength and failure mode of test pieces from a butt-fused joint

Brittle  Mixed  Ductile
Mechanical and Non-destructive Testing of Plastics Welds

ISO standards

- ISO 13954:1997 Plastics pipes and fittings. Peel decohesion test for polyethylene (PE) electrofusion assemblies of nominal outside diameter greater than or equal to 90mm.
ISO standards

- ISO 13955:1997 Plastics pipes and fittings. Crushing decohesion test for polyethylene (PE) electrofusion assemblies
Mechanical and Non-destructive Testing of Plastics Welds

Other standards/specifications

• Lining membranes
  – ASTM D4437:1999 Standard practice for determining the integrity of field seams used in joining flexible polymeric sheet geomembranes
  – ASTM D6392:1999 Standard test method for determining the integrity of nonreinforced geomembrane seams produced using thermo-fusion methods
  – DVS 2226 Testing of fused joints on liners of polymer materials
    • Part 1: Testing procedure, requirements
    • Part 2: Lap shear test
    • Part 3: Peeling test
    • Part 4: Tensile creep test on PE
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Training and Qualification of Plastics Welders

- EN 13067:2003 Plastics welding personnel – Qualification testing of welders – Thermoplastics welded assemblies
- EWF 581-01:2004 Minimum requirements for the education, examination and certification of European Plastics Welders
- AWS B2.4:2006 Specification for welding procedure and performance qualification for thermoplastics
- ISO/TR 19480:2005 Polyethylene pipes and fittings for the supply of gaseous fuels or water – Training and assessment of fusion operators
Training and Qualification of Plastics Welders

EN 13067

Welding processes

- Hot gas
  - Round nozzle
  - High speed nozzle
  - Wedge
- Extrusion
- Heated tool
- Electrofusion
  - Butt
  - Saddle
  - Socket
  - Wedge

Materials

- Sheet, pipe and fittings
  - PVC
  - PP
  - PE
  - PVDF
  - ECTFE, FEP, PFA
- Lining membrane
  - PE
  - PVC-P
  - ECB
## EN 13067 – Welding categories

- **39 categories**
  - Defined by material, product type, dimensions and welding process
- **Polypropylene:**

<table>
<thead>
<tr>
<th>Category</th>
<th>Product type</th>
<th>Dimensions</th>
<th>Welding process</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Sheet</td>
<td>All thicknesses</td>
<td>Hot gas (high speed nozzle)</td>
</tr>
<tr>
<td>2.2</td>
<td>Sheet</td>
<td>Thickness ≥ 3mm</td>
<td>Extrusion</td>
</tr>
<tr>
<td>2.3</td>
<td>Sheet</td>
<td>Thickness ≥ 3mm</td>
<td>Heated tool (butt)</td>
</tr>
<tr>
<td>2.4</td>
<td>Pipe</td>
<td>Diameter ≤ 315mm</td>
<td>Heated tool (butt)</td>
</tr>
<tr>
<td>2.5</td>
<td>Pipe</td>
<td>Diameter &gt; 315mm</td>
<td>Heated tool (butt)</td>
</tr>
<tr>
<td>2.6</td>
<td>Pipe</td>
<td>All diameters</td>
<td>Heated tool (socket)</td>
</tr>
<tr>
<td>2.7</td>
<td>Pipe</td>
<td>All diameters</td>
<td>Electrofusion (socket)</td>
</tr>
</tbody>
</table>
EN 13067 – Examination entry requirements

- Completed an Apprenticeship as a plastics fabricator, or
- At least two years experience as a plastics welder (Employer verification), or
- Completed a technical and practical training course in preparation for the examination
Training and Qualification of Plastics Welders

EN 13067 – Examination procedure

- **Theoretical test**
  - Minimum of 20 multiple-choice questions
  - Relevant to the categories being taken

- **Practical test**
  - Welding a standard test-piece for each category being taken
Training and Qualification of Plastics Welders

EN 13067 – Examination procedure

• Theoretical test
  – Correct preparation of work pieces
  – Types of imperfections
  – Operation of welding and ancillary equipment
  – Health & safety
  – Characteristics of thermoplastics used
  – Non-destructive and destructive tests
  – Preventing and correcting welding faults
  – Welding procedure specification/welding record sheet
Training and Qualification of Plastics Welders

EN 13067 – Examination procedure

- **Practical test**
  - **Hot gas/extrusion**
    - PVC
      - 5mm sheet, single V
    - PP/PE
      - Hot gas: 10mm sheet, double V
      - Extrusion: 10mm sheet, single V with backing run
    - PVDF
      - 4mm sheet, single V
Training and Qualification of Plastics Welders

EN 13067 – Assessment of examination

- **Theoretical test**
  - Pass mark: 80%

- **Practical test**
  - Test piece visually examined
  - Specimens cut from test piece and mechanically tested

<table>
<thead>
<tr>
<th>Mechanical test</th>
<th>Relevant standard</th>
<th>Examination categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bend</td>
<td>EN 12814-1</td>
<td>All welds in sheet except ECTFE Heated tool butt welds in PP and PVDF pipe</td>
</tr>
<tr>
<td>Tensile</td>
<td>EN 12814-2</td>
<td>Hot gas welds in ECTFE sheet Heated tool butt welds in PE and ECTFE pipe</td>
</tr>
<tr>
<td>Decohesion</td>
<td>EN 12814-4</td>
<td>Socket welds in large diameter pipe</td>
</tr>
<tr>
<td>Crush</td>
<td>EN 12814-4</td>
<td>Socket welds in small diameter pipe</td>
</tr>
<tr>
<td>T-peel</td>
<td>EN 12814-4</td>
<td>Welds in lining membranes</td>
</tr>
</tbody>
</table>
Training and Qualification of Plastics Welders

EN 13067 – Assessment of examination

- Hot gas/extrusion
  - Ends of test piece discarded
  - Six bend test specimens cut from remaining test piece
  - Each specimen subjected to a bend test
Bend test

- If all six test specimens achieve minimum required bend angle (MBA)
  - PASS

- If one test specimen fails to achieve MBA
  - cut out and test two additional test specimens
  - if both specimens achieve MBA
  - PASS
  - if one or both fail to achieve MBA
  - FAIL

- If more than one specimen fails to achieve MBA
  - FAIL
Training and Qualification of Plastics Welders

EN 13067 – Approval period

• Initial Approval
  – two years
  – interruption period no longer than 6 months
  – Welder’s work acceptable (company confirmation)

• Prolongation
  – further two years
  – requirements as for initial approval
  – plus proof of welding quality
    • mechanical test results from independent test house

• Maximum approval period of four years
Training and Qualification of Plastics Welders

EN 13067 – Approval period

- Examination passed
  - Year one certificate
    - Submission of 12-month confirmation of activity
      - Year two certificate
        - Submission of prolongation application form plus proof of weld quality
          - Year three certificate
            - Submission of 36-month confirmation of activity
              - Year four certificate
                - Re-examination
Training and Qualification of Plastics Welders

EWF 581-01

- European Federation for Welding, Joining and Cutting guideline
- Examination entry requirement in EN 13067
  - Completed a technical and practical training course in preparation for the examination
- For each category defined in EN 13067
  - EWF 581-01 defines the minimum theoretical education and practical training
  - In terms of content and training hours
## Training and Qualification of Plastics Welders

### EWF 581-01 – Education and training

- **Theoretical education**
  - hot gas/extrusion welding

<table>
<thead>
<tr>
<th>Element</th>
<th>Theme</th>
<th>Minimum Teaching Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Materials technology of plastics</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Processing of thermoplastics</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Welded joints and terminology</td>
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</tr>
<tr>
<td>4</td>
<td>Basics of hot gas welding</td>
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<tr>
<td>5</td>
<td>Welding rework</td>
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<tr>
<td>6</td>
<td>Health and safety</td>
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</tr>
<tr>
<td>7</td>
<td>Testing welds and joints</td>
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<td>8</td>
<td>Weld imperfections</td>
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<td>9</td>
<td>Documentation</td>
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<tr>
<td>10</td>
<td>Basics of extrusion welding</td>
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<td><strong>Total</strong></td>
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<td><strong>8</strong></td>
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</table>
## Practical training

- **hot gas/extrusion welding**

<table>
<thead>
<tr>
<th>Training Unit</th>
<th>Process</th>
<th>Material</th>
<th>Content</th>
<th>Minimum Time, Hours</th>
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<tbody>
<tr>
<td>General</td>
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<td>Material identification, equipment, hand tools, weld preparation</td>
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<tr>
<td>P1.1</td>
<td>Hot gas speed nozzle</td>
<td>PP</td>
<td>Double V-butt welding</td>
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<td>P1.2</td>
<td>Hot gas speed nozzle</td>
<td>PE</td>
<td>Double V-butt welding</td>
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<tr>
<td>P1.3</td>
<td>Hot gas round nozzle</td>
<td>PVC</td>
<td>Single V-butt welding</td>
<td>5</td>
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<td>P1.4</td>
<td>Hot gas speed nozzle</td>
<td>PVC</td>
<td>Single V-butt welding</td>
<td>5</td>
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<tr>
<td>P1.5</td>
<td>Hot gas speed nozzle</td>
<td>PVDF</td>
<td>Single V-butt welding</td>
<td>5</td>
</tr>
<tr>
<td>P1.6</td>
<td>Hot gas speed nozzle</td>
<td>ECTFE or PFA or FEP</td>
<td>Single V-butt welding</td>
<td>5</td>
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<tr>
<td>P1.7</td>
<td>Extrusion</td>
<td>PP</td>
<td>Single V-butt welding</td>
<td>5</td>
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<tr>
<td>P1.8</td>
<td>Extrusion</td>
<td>PE</td>
<td>Single V-butt welding</td>
<td>5</td>
</tr>
</tbody>
</table>
Training and Qualification of Plastics Welders

AWS B2.4

• Approved American National Standard
• Specifies qualification of welding personnel and procedures
• Main differences to EN 13067
  – Specifies separate qualification for
    • vertical, overhead and horizontal welding positions
    • different makes/models of welding equipment
    • PVDF copolymers
    • ECTFE/ETFE and MFA/FEP/PFA
    • Pipe OD ranges: ≤ 1.25”, 1.5-3”, 4-10”, >10”
ISO/TR 19480

• Main differences to EN 13067
  – PE pipe only
    • Butt fusion, electrofusion, socket fusion
  – Tear test specified for saddle assemblies
Training and Qualification of Plastics Welders

Current developments

- **EN 13067**
  - CEN/TC249/WG16
    - UK Principal Expert: Mike Troughton (TWI)
    - Modifications to examination test piece dimensions
    - Addition of solvent welding of PVC, cPVC and ABS pipes and welding of flexible PP lining membranes

- **EWF 581-01**
  - EWF WG “Plastics Welding”
    - UK Principal Expert: Mike Troughton (TWI)
    - Division of document into two separate guidelines
      - Pipes
      - Fabrication and lining membrane

- **AWS B2.4**
  - AWS Subcommittee B2F
    - UK Principal Expert: Mike Troughton (TWI)
    - Addition of solvent welding of PVC, cPVC and ABS pipes
Thank you