DISTRIBUTION NETWORKS ELECTROFUSION JOINT QUALITY

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Introduction

Small diameter PE electrofusion joints are widely used in potable water distribution connections from 100 mm PVC mains in culs de sac, fuel gas distribution, and vacuum and pressure sewers especially in soil conditions with high water tables.

The size range DN ≤63 mm may be regarded as a separate category, as distinct from larger diameter electrofusion joints, when considering field quality and joint testing procedures. It is estimated[1] that this size range accounts for approximately 40% of all electrofusion joints used.

Site inspections, and laboratory testing, over a 20 year period shows a lesser attitude to these sizes regarding installation quality when compared the large diameter joints. There is a historic use of hand scraping of pipes (rotary peelers being resisted due to cost); and often no use of alignment clamps especially with coiled pipes.

Several of the currently available Standard physical testing methods are not suitable for these diameter ranges due to the geometries of the electrofusion fittings. The relatively thin wall sections of both the electrofusion fittings, and the pipes, prevent test specimens being prepared to meet various Standards geometries, and subsequent testing.

Standard Testing Methods

ISO 13954 Peel Testing

Whilst this Test Method[2] is scoped as applying to diameters DN90 and above, a test program was carried out on DN63 electrofusion joint assemblies to determine if this test principle could be applied to smaller diameters than the notational DN90 size.

Test specimens using smaller pin/hole dimensions than those listed in Fig 3 of ISO 13954 were prepared and then peel tested as described in ISO 13954.

This proved to be unsuitable as the wall thickness of the electrofusion fittings resulted in the load attachments pulling out of the PE material before any significant loading could be applied across the fusion zone.

It should be noted that there is considerable concern with ISO 13954 replicating the actual stress patterns in a pressurised electrofusion joint assembly. Finite Element Analysis (FEA)[3,4] studies previously performed on models of pressurised electrofusion joints have shown the maximum stress location to be at the inner hot zone section of the joint. In contrast, the ISO 13954 test method applies the maximum stress at the outer hot zone section of the joint.

The visual assessment criteria in ISO 13954 and ISO 4427[5] are considered inadequate, and this has been addressed in the 2020 edition of AS/NZS 4129 – Fittings for use with PE pipeline systems.[4]

In this document, the additional visual assessment requirements have been included over and above those in ISO 4427 :-

" Where voids are present in the fusion plane, these shall be regarded as part of the brittle length. Where rupture occurs through the pipe or fitting wall thickness this shall be regarded as a ductile result."

ISO 21751 Strip Bend Testing

A test program was undertaken using DN63 mm PE electrofusion coupling assemblies with samples of five different brands of fittings commonly available. The samples were taken from a combination of on-site installations, and those prepared under laboratory workshop conditions.

The aim of the test program was to establish if the ISO 21751 Method of Test[6] could be reliably applied to DN63 mm sizes, taking into account the varying wall thickness of each different brand of fitting. Measured section thicknesses for each fitting brand were :-

Electrofusion Coupling Brand	Fitting Wall Thickness Inner Fusion Zone	Fitting Wall Thickness Outer Fusion Zone	Pipe Wall Thickness
1	9.6	9.2	5.1
2	9.4	9.8	6.3
3	8.1	7.7	6.1
4	8.4	8.0	6.1
5	9.0	7.3	6.6

Table 1 - Wall Thickness Dimensions Pipes/Couplings

Test strips were prepared as detailed in ISO 21751 from a range of specimens prepared from all of the fittings brands listed in Table 1 above, and testing was carried out on both fusion zones in each coupling assembly. Two widths of bending grips were used, 10 mm as per ISO 21751, and additional testing with an 80 mm wide grip to attempt to spread the torsion loads across the PE sections.

All tests performed showed the grips damaging the thin PE pipe/fitting wall thicknesses without applying a full stress level across the fusion plane. From this it is concluded that the ISO 21751 test method is not suitable for testing electrofusion joints of DN ≤ 63 mm sizes.

Brands	ISO 21751 10 mm grip Decohesion/damage	ISO 21751 80 mm grip Decohesion/damage	ISO 13955 Decohesion C_c %
1	0%/Yes	0%/Yes	0
2	0%/Yes	0%/Yes	0
3	0%/Yes	0%/Yes	0
4	0%/Yes	0%/Yes	0
5	0%/Yes	0%/Yes	0

Table 2 - ISO 21751 Strip Peel Test Results

ISO 13955 Crushing Decohesion Testing

Testing to ISO 13955[7] was performed across the five brands of DN63 mm electrofusion fittings, (using approximately 130 joint sections) with a variety of hand scraping/rotary peeling, PE80B/PE100 materials, weathered, and non peeled pipes being examined.

Variable peel depth alone (both rotary and hand scrape) showed little effect on the decohesion brittle C_c results for all of the fitting brand types.

Fitting Brand	Peel Depth Range mm	Decohesion Range Brittle C_c %
1	0.1 – 0.26	0
2	0.1 – 0.35	0
3	0.12 – 0.2	0
4	0.1 – 0.2	0
5	0.1 – 0.3	0 - 6.5

Table 3- Variable peel depth brittle decohesion

Specific defects were introduced into joint assemblies and the crush decohesion brittle C_c behaviour recorded.

Specific Defect	Decohesion Range Brittle C_c %	Comments
Pipe/socket misalignments	38.5 - 46.2	
Incomplete spigot insertions	38.5 - 100	PE melt flow visible inside socket
Dirt contamination on pipe surfaces	90.0 - 100	Contamination visible on socket fusion zone
New pipes no peeling	81.0	Some bonding observed
Weathered pipes no peeling	100	Some very low level bonding observed
Weathered pipes hand scraped	0	Hand scrape depth 0.1 – 0.2 mm

Table 4 - Various defects brittle decohesion

All the electrofusion couplings used were marked as be made from PE 100 material. The pipes were a combination of PE100(HDPE) and PE80B(MDPE) materials.

There was no observable difference in test results between assemblies using PE100 coupling/PE100 pipe, and PE100 coupling/PE80B pipe combinations.

Visual Quality Evidence & Records

All the electrofusion joint assembly samples were assessed for installation quality requirements taking into account the following criteria

1 Cleaning

If pipe branding was visible at the end of the electrofusion coupling, cleaning was carried out with clean cloth/ethanol to determine if the branding could be removed.

2 Witness marks

Witness marks present on each side of the coupling, marked without damage to the pipe surface. Witness marks that were visible on both pipe/coupling ends regarded as suspect as being applied after the joint was assembled.

3 Joint alignment

Both pipes aligned in the socket without angles, or socket rotation. Assembly held immobilised over full heating and cooling times.

4 Pipe peeling

Both pipes show visible peeling around the pipes. Measure depth of peeling and compare against 0.2 mm – 0.3 mm depth criteria.

5 Melt indicator pins

Both melt indicator pins fully, and evenly risen. Take into account different pin appearance with different brand designs.

6 Melt spillage

No evidence of PE melt, or heating wires, visible at the ends of the fitting.

7 Control box records

Complete records of nominated voltage, full completion of standard fusion time, and cooling time actually achieved are available from calibrated control boxes.

As noted in the test results tables, a number of the on-site produced samples did not meet all of these criteria. In addition, specific defects were introduced into a number of the laboratory test samples.

Conclusions

The aim of this program was to identify a quality system specifically for small diameter electrofusion joints (DN ≤63 mm) using readily available and established testing methods.

The inspection and testing program was carried out across a large number of joints taken from five of the most commonly available brands of couplings.

This program indicated that the ISO 13954, and ISO 21751 methods of test (or modifications) were not suitable for this size range of joint assemblies.

It was concluded that an on-site installation quality assurance program should include a combination of :-

1. Visual acceptance criteria of the seven elements discussed above
2. Decohesion crush testing to ISO 13955 on samples taken from site, based on a statistical test sampling plan
3. A Safe Work Method Statement (SWMS) including all jointing details and procedures be established, and agreed to, before construction commences.

References

1. Private communications
2. ISO 13954 – Peel decohesion test for PE electrofusion assemblies of nominal outside diameter $\geq$ 90 mm.
3. M.Troughton et al. Comparison of long term and short term tests for electrofusion joints in PE pipes. Plastics Pipes Conference. PPXIII 2006 Washington DC.
4. D.S.Sarambale & D.K.Shinde. Int J of Mech and Prod Eng. Pp 51 – 54 V5 Issue 12 Dec 2017.
5. AS/NZS 4129 – Fittings for PE pipes for pressure applications
6. ISO 4427.3 – PE pipes and fittings for water supply; Part 3 Fitting
7. ISO 21751 - Decohesion test of electrofusion assemblies – strip bend test
8. ISO 13955 – Crushing decohesion test for PE electrofusion assemblies