Butt fusion welding of Polyethylene water Pipe

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Mechanical Testing for Butt Fusion Joints in Polyethylene Pipes

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Introduction

PE pipe or fittings are joined to each other by heat fusion or with mechanical fittings.PE pipe may be joined to other pipe materials by means of compression fittings, flanges, or other qualified types of manufactured transition fittings. There are many types and styles of fittings available from which the user may choose. Each offers its particular advantages and limitations for each joining situation the user may encounter. Contact with the various manufacturers is advisable for guidance improper applications and styles available for joining as described in this document. The joining methods discussed in this chapter cover both large and small diameter pipe. Large diameter PE pipe is considered to be sizes 3” IPS (3.500” OD, Iron Pipe Size) and larger. All individuals involved in the joining PE pipe systems, whether it be using the typical heat fusion methods or employing mechanical connections, should be fully trained and qualified in accordance with applicable codes and standards and/or as recommended by the pipe or fitting manufacturer. Those assigned to making joints in PE pipe for gas applications must meet the additional requirement of compliance with U.S. Department of Transportation Pipeline Safety Regulations (10). The equipment used in the process of making heat fused joints must be designed to operate for the selected pipe and fusion procedures. Additionally, the equipment should be well maintained and capable of operating to specification.

Butt fusion

Butt fusion is probably the most common technique for welding PE pipe. The ends of each length of pipe are heated to start to melt the PE, then pushed together so that as they cool they form a permanent bond together.

Butt fusion welding requires a rig to make sure the pipes are level and their faces flat as they’re pressed together to form a continuous seal around the circumference of the joint. The rigs vary in size depending on the diameter of pipe being used, butt fusion is typically available for pipe diameters from 50mm to 2m. I've included a photo below from a project using butt fusion joints to weld 710mm diameter pipe as is was sleeved though an existing abandoned pipe.

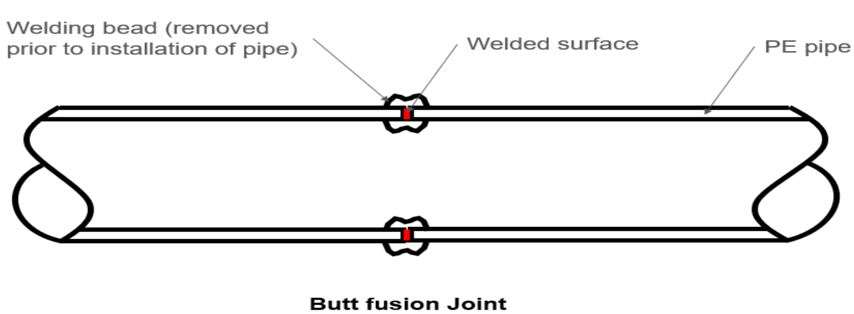

Figure -1-

Advantages of Butt Welding

• No special insert is required for jointing.

• Fittings such as elbows and "T" can be produced with butt welding.

• It is easy to obtain the welding machine. It is produced in our country. It is an easy method.

• Fittings are cheaper.

• It can be applied easily to pipes having diameter more than Ø63 (wall thickness greater than 3mm)

• Lip-welds formed inside and outside as a result of the application increase the weld cross section which increases the safety.

• It is a reliable, appropriate welding process.

• When a suitable welding connection is made the strength of the welded area will be equivalent to the strength of the main pipe

Preparation of welding:

Before you start the operation, it is important to prepare the work area.

Step 1

- Select the operation area that is suitable for the work.
- Install the protection tent or other equipment to protect the welding zone against rain, sunshine or bad weather (if required)
- Set up the welding machine with all the accessories according to the welding pipe size. Check if the machine is functioning.
- All of the problems or missing parts must be fixed prior to the start of the welding operation.

Step 2

- Insert two pipes ends on both side of the machine clamps, protrude approx. 3; 5 cm. from each shell side, clamping and adjust the pipe or piping part, the surfaces to be welded should be parallel to each other.
- Adjust the alignment of pipe line by tightening or losing bronze nuts on the top aluminum clamps.
- Secure longitudinal movement of the parts to be welded by taking appropriate measures.
- Clean outside and inside pipe surface.

Figure -2-

Step 3

- Insert the facing tool or trimmer between the two pipe ends into the lock position on the welding machine.

Figure-3-

Step 4

- Start the facing tool or trimmer by turning on the control switch.
- Slowly approach the pipe ends towards the facing tool or trimmer by controlling the directional valve on hydraulic control unit while keeping control pressure a little higher.
- The cutter will cut the surface of both pipe ends making them clean, plane and parallel.

Step 5

- When the pipe ends had been trimmed squarely and with an even thickness, slowly decrease the pressure before switching off.
- Remove the facing tool or trimmer from welding machine to the support frame and clear the facing scraps from pipe ends.
- Inspect the ends, they must be clean and plane; otherwise repeat the step 3 – 5 again.
- During the clearing and inspection, avoid any contact with the surface of pipe ends.

Figure-4-

Step 6

- Recheck the alignment of the pipeline by bringing the pipe ends closely together and measure the actual tolerance.
- The misalignment value between both pipe ends should not be more than 10% of the pipe wall thickness.
- The gap width is the allowance between the treated pipe ends, should not exceed the value shown on Table 2.
- If they are not in the control tolerance, then repeat the steps 2-5 again

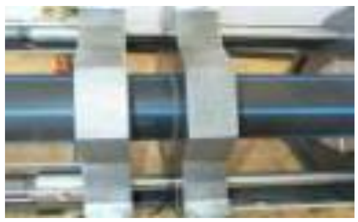

Figure-5-

Step 7

- During the alignment checking in step 6, the welder team must measure the force or pulling pressure (drag pressure) by looking and recording the data found at the pressure indicator device

- The pressure must be created to pull the whole work piece moving in between welding process.
- The drag pressure is the additional value that must be added up to the alignment pressure (P1) and joining pressure (P3) from calculation or machine pressure data for each operation area and every welding joint.

Step 8

- The welding team to prepare the welding parameter by calculating using the recommended values according to Table 1, Table 3 or machine data for the welding operation control.
- Check the heating plate temperature on the setting range according to step 1; cleaning both heating plate side with cleaning agent and insert its back to support while waiting for welding operation to start.

Step 9

- Bring the pipe ends apart, to clean both pipe ends using coat with an ethyl; alcohol or other suitable cleaning agent and avoided any contact to the surface after cleaning.
- Repeat the cleaning process, if necessary.

Step 10

- To start with the welding process, begin with the alignment stage by inserting the heating plate between the two pipe ends, moving both pipe ends close together until contact with the heating plate.
- Start the buildup pressure to the alignment pressure level (P1 + drag pressure), maintain the pressure until there are welding seam appear.

Figure-6-

Step 11

- In this stage, the uniform bead should had been created between the heating plates throughout the whole circumference of both pipe ends.
- The pressure must be maintained until the bead height according to the calculation value in table 1 by visual inspection.
- Continue to the heating; up stage by reducing pressure and maintaining the heating; up pressure level (P2) along heating; up time (T2).

Step 12

- Open both pipe ends, carefully remove the heating plate without touching the melted area and see to it that the removing time should not be longer than the changeover time (T3), insert heating plate to the support.

Figure -7-

Step 13

- Immediately increase pressure up to the joining pressure level (P3 + drag pressure) within the joining pressure built; up time (T4)
- Uniform beads must be created throughout the whole circumference of the pipe joints.
- Maintain or Keep the joining pressure constant throughout the cooling time (T5) or until the welding joint cools down. Avoid forced cooling down by applying water.

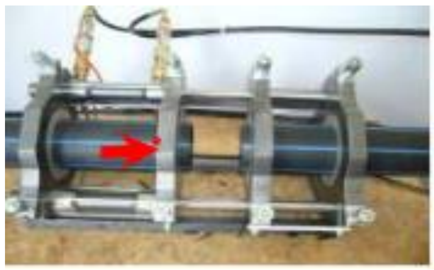

Figure-8-

Step 14

- Remove the clamps after the cooling stage is complete.
- Welding bead of each jointing has to be visually inspected and measured based on the following:
  -both ends should be almost equal in dimension
  - The bead surface should be smooth and do not shine.
  -Bead width must be according to the limit dimension
- Possible differences in the formation of the beads may be justified by different behavior of the joined materials.

Step 15

- All the welding information must be recorded into the data logger, log sheet or welding protocol form.

Table1. Welding Parameter and control for calculation method and recommended values to be use

Descript	Parameter	Calculation	Recommended Valuese
1. Heating temperature	200 - 220 0C	-	-
2. Alignment pressure (bar)	0.15 ± 0.01 N/mm2	5 + (0.75 x e	-
3. Alignment time (Bead Created)	Until bead created follow item 4	Until bead created follow item 4	Table3
4. Bead height (m	+ (0.1 x e)	5 + (0.1 x e)	-
5. Heating-up pressure (bar)	≤ 0.02 N/mm2	A1 / A2 x 0.2	-
6. Heating-up time (sec.)	10 x e	10 x e	Table3
Changeover time (sec.)	3 + (0.01 x OD)	3 + (0.01 x OD)	Table3
8. Joining pressure built-up time (sec.)	3 + (0.03 x OD)	3 + (0.03 x OD)	Table3
9. Joining pressure (bar)	0.15±0.01 N/mm2	A1 / A2 x 1	-
10. Minimum cooling time (min.)	3 + e	3 + e	Table3
11. Minimum bead width (mm	3 + (0.50 x e)	3 + (0.50 x e	Table3
12. Maximum bead width (mm)	5 + (0.75 x e)	5 + (0.75 x	Table3

OD = Outside Diameter (mm.), e = Wall Thickness (mm.)

A1 = Pipe section area (mm2) by calculation formula: [(OD2– ID2)/4]

A2 = Hydraulic cylinder section area (mm2) by calculation formula: [(Number of hydraulic cylinder) x (iD2Cylinder– OD2Shaft)/4]

Gap width

The joining areas have to be plane with a clean and grease-free tool directly before the welding, so they are plane-parallel in clamped condition. The gap width and the misalignment have to be controlled. The misalignment of the joining areas on the pipe outside respect may not pass the permissible value of 0.1 x wall thickness 0.1 x wall thickness 0.1 x wall thickness 0.1 x wall thickness of pipe. The permissible gap width under alignment pressure is show on Table2.

Table2. The maximum gap width is allowance between the treated welding zones.

Pipe outside diameter range (mm.)	Gap width (mm.)
< 355	0.5
400...< 630	1.0
630...< 800	1.3
800...< 1000	13
> 10	2.0

Table3. Recommended values for the heating tool butt----fusion welding of pipes, and fittings from HDPE, at an ambient temperature of approximately 20 C and moderate air flow (Interim values have to be interpolated).

Nominal wall Thickness (mm)	**Alignment**	**Heating---up**(T2)	**Changeover (T3)**	**Joining**	
	Bead height on heating tool at the end of the alignment time (alignment with 0.15 N/mm²) (mm) minimum values	Heating-up time =10 x wall thickness (heating-up with < 0.02 N/mm²) (second)	(second) maximum time	(T4) Joining Pressure build-up time (second)	(T5) Cooling time under joining pressure P=0.15 N/ mm² + 0.01 (minute) minimum
<4.4	0.5	45	5	5	6
4.5-7	1.0	45-70	5-6	5-6	6-10
7-12	1.5	70-120	6-8	6-8	10-16
12-19	2.0	120-190	8-10	8-11	16-24
19-26	2.5	190-260	10-12	11-14	24-32
26-37	3.0	260-370	12-16	14-19	32-45
37-50	3.5	370-500	16-20	19-25	45-60
50-70	4.0	500-700	20-25	25-35	60-80

2. Mechanical tests for butt fusion joints

The PE pipes industry uses a number of different mechanical tests to verify the quality of butt fusion joints, depending on the industry and country. For example, in the US a manual bend test is defined in ASTM F2620 (6) and a high-speed tensile impact test is also commonly specified, as defined in ASTM F2634 (7). In the UK, a tensile test using a wasted test specimen is defined in WIS 4-32-08 (8) and in Germany a technological bend test is defined in DVS 2203-5 (9), a tensile test is defined in DVS 2203-2 (10) and a tensile creep test is defined in DVS 2203-4 (11). There are also a number of international standards that specify mechanical test methods for butt fusion joints in PE pipes, including ISO 13953 (12), EN 12814-1 (13), EN 12814-2 (14), EN 12814-3 (15), EN 12814-6 (16) and EN 12814-7 (17). In addition, in most specifications for butt fusion joints in PE pipes, hydrostatic pressure testing, both short-term and long-term, are defined.

2.1. Bend Tests

A typical bend test, such as the one defined in EN 12814-1, uses a parallel-sided test specimen, an example of which is shown in Figure 9. This is then subjected to a three-point bend, as shown in Figure 10. In this standard, the tests are performed at room temperature, using a ram displacement velocity of 50mm/min. The ram displacement or bend angle at which either fracture occurs or a crack appears is measured.

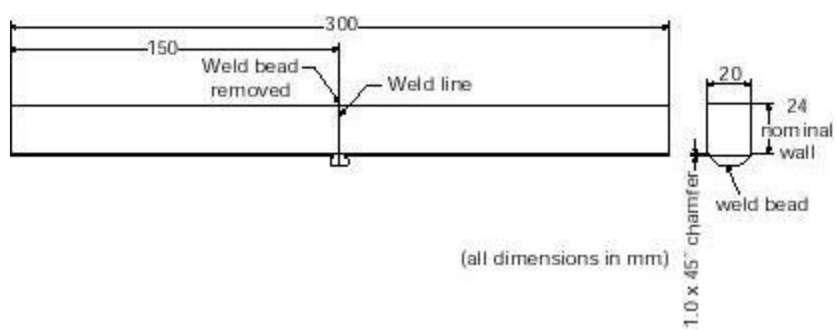

Fig. 9 Typical geometry and dimensions of bend test specimen, as defined in EN 12814-1

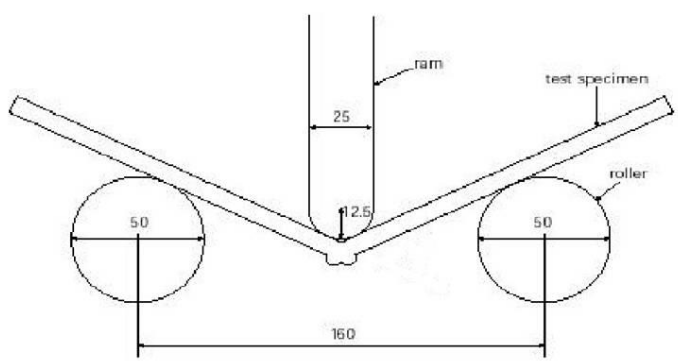

Fig. 10 Schematic diagram of bend test as defined in EN 12814-1

2.2 Tensile Tests

There are a number of tensile test specimen geometries, the most common are: parallel-sided, dumb-bell or dog-bone, and wasted. A typical dumb-bell specimen geometry is shown in Figure 11.

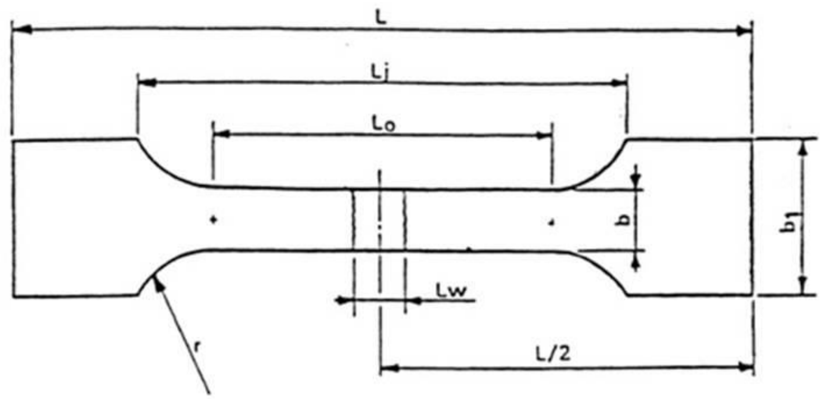

Fig. 11 Typical geometry of dumb-bell tensile test specimen, as defined in EN 12814-2

In EN 12814-2 the tests are carried out at room temperature, using a crosshead speed of 50mm/min. Both fused and parent pipe reference specimens are tested and a short-term tensile welding factor, ƒs, is then determined, defined as:

$$f_s = \frac{\text{yield strength of fused specimen}}{\text{yield strength of parent material}}$$

A typical wasted tensile test specimen is shown in Figure 12.

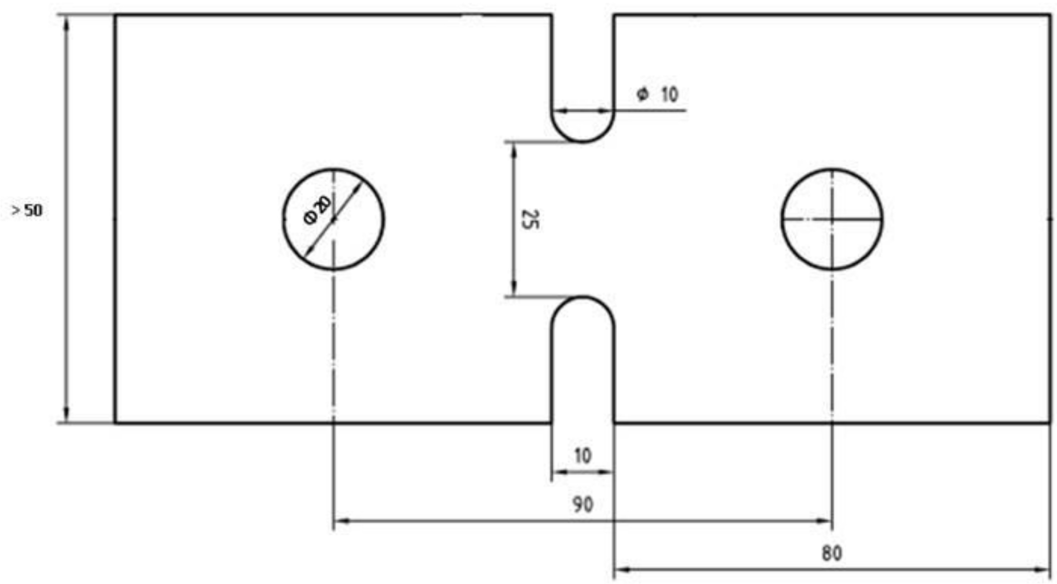

Fig. 12 Typical geometry of wasted tensile test specimen, as defined in EN 12814-7

In ISO 13953, the tests are carried out at room temperature and at a constant speed of 5±1mm/min. The failure mode (ductile or brittle – see Figure 13) and tensile strength are used as criteria for the evaluation of the joint.

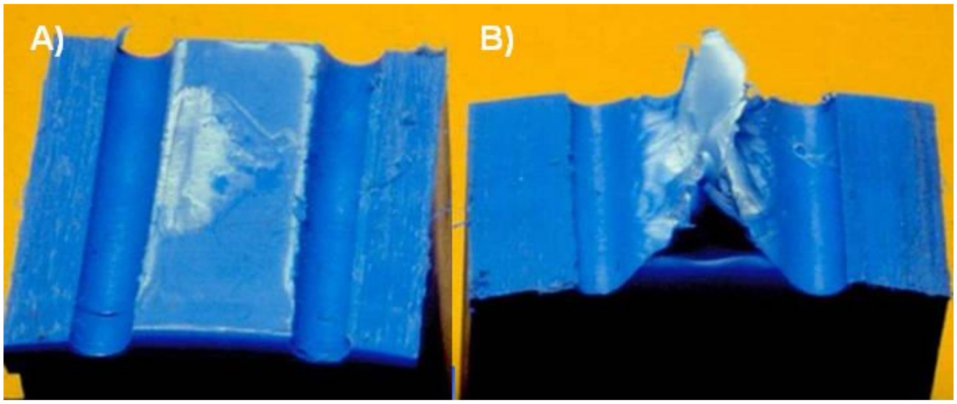

Fig. 13 Example of: a) brittle failure and b) ductile failure in a tensile test with a wasted specimen geometry

In EN 12814-7, the specimen extension is measured using an extensometer and the energy to break the specimen is calculated from the area under the load vs extension curve. Specimens are cut from both the butt fusion joint and the parent pipe and a tensile energy welding factor, ƒe, is calculated, where:

$$f_e = \frac{\text{average energy to break of fused specimens}}{\text{average energy to break of specimens from parent pipe}}$$

2.3. High Speed Tensile Impact Test

The testing of butt fusion joints in tensile impact mode is defined in ASTM F2634. The specimen geometry and dimensions are given in Figure 14. The speed of the test is 6 inches/s for wall thicknesses between 0.25 and 1.25 inches, and 4 inches/s for wall thicknesses greater than 1.25 inches. Specimens are tested to failure and the energy to yield and to break are calculated, and the failure mode (ductile or brittle) is recorded.

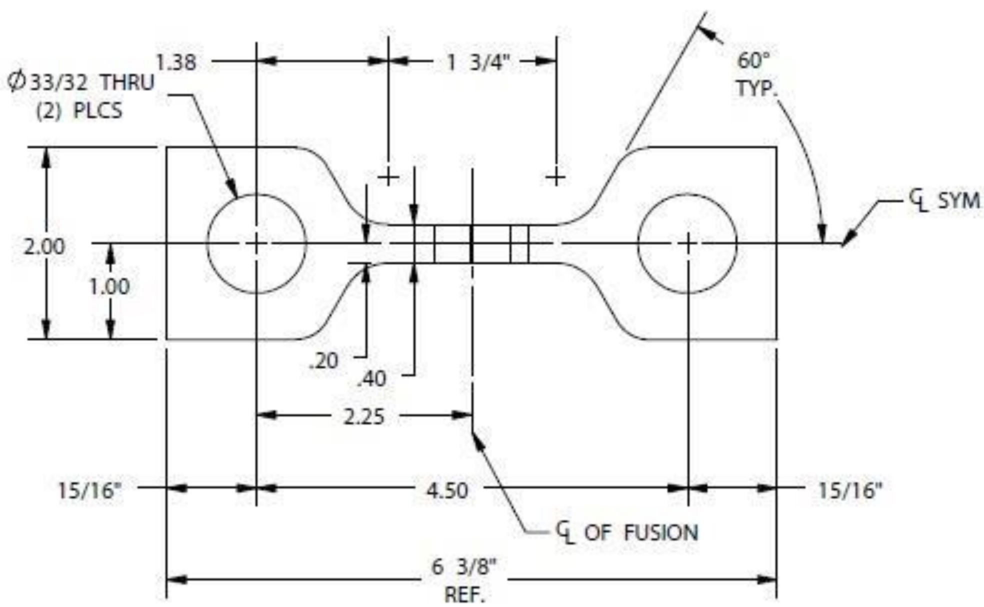

Fig. 14 High speed tensile impact test specimen geometry, as defined in ASTM f2634

2.4. Whole Pipe Tensile Creep Rupture Test

This test was developed at TWI (20) specifically to determine the long-term performance of butt fusion joints in PE pipes. In this test, which is defined in Annex B of EN 12814-3, a welded whole pipe sample is subjected to a constant axial tensile load, in water at 80°C. A schematic of the test equipment is shown in Figure 15. The load is applied by a hydraulic jack and transferred to the end of the pipe via a push rod. The time to failure is recorded for a specific test load and the location of failure noted.

The advantage of this test over the coupon creep rupture test is that all of the residual stresses in the joint are retained, which is more representative of the pipe's stress state in service.

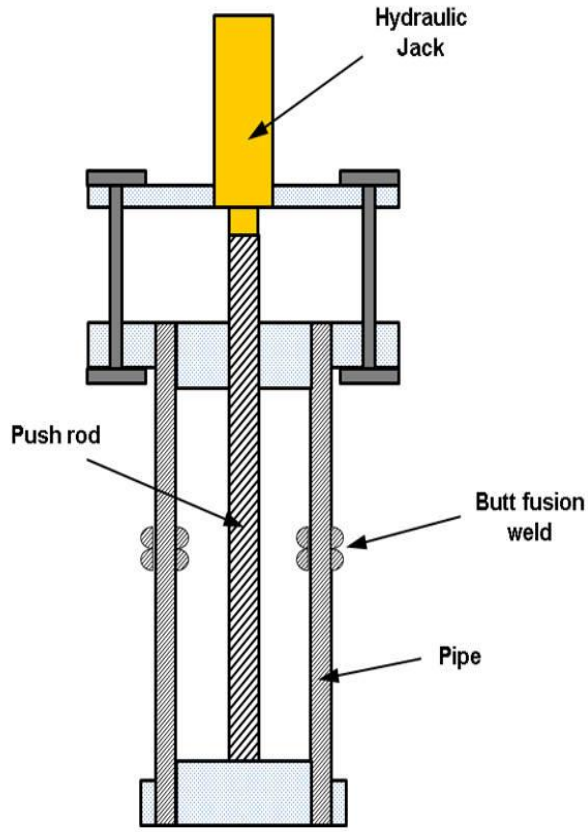

Fig. 15 Whole pipe tensile creep rupture test, according to ANNEX B of EN 12814-3

2.5. Coupon Creep Rupture Test

The main standardized test method for determining the long-term performance of welded PE specimens is the tensile creep test according to EN 12814-3 or DVS 2203-4. This is basically a stress rupture test in which dumb-bell specimens are subjected to a constant load at elevated temperature (normally 80°C) and the time to failure is recorded. A schematic of the test equipment is shown in Figure 16.

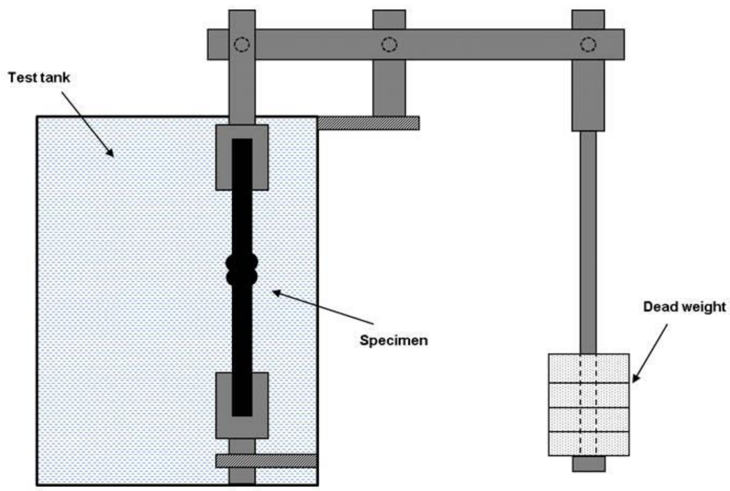

Fig. 16 Tensile creep rupture test rig, according to EN 12814-3

2.6 Hydrostatic Pressure Tests

Short-term hydrostatic pressure tests, or hydro-tests, are normally specified during pipeline installation in order to prove that the system is leak-proof (18). These tests typically involve pressurizing the welded pipeline, or section of pipeline, with water to a pre-determined level. This pressure is then maintained for a period of time (typically 30 minutes) by injecting additional water to allow for creep in the material. After this time, the pressure is locked and the decay, due to further creep of the pipeline, is monitored over time (typically 60 minutes). This pressure drop must not be greater than a pre-set value in order to pass the test.

Long-term hydrostatic pressure tests are used for assessing the long-term behavior of pipes containing fused joints under internal pressure at elevated temperature and are defined in the standard EN ISO 1167 (19). Fused pipe samples are closed using end caps, filled with water and subjected to an internal hydrostatic pressure and an elevated temperature (typically 80°C). The time to failure is measured and the position of failure recorded.

Reference:

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6. ASTM F2634-10, 2010, “Standard test method for laboratory testing of polyethylene (PE) butt fusion joints using tensile-impact method”, ASTM International, West Conshohocken, PA, USA.

7. ISO 13953, 2001, “Polyethylene (PE) pipes and fittings- Determination of the tensile strength and failure mode of test pieces from a butt-fused joint”, International Organization for Standardization, Geneva, Switzerland.