

**Guidance for Field Hydrostatic Testing Of
High Density Polyethylene Pressure Pipelines:
Owner's Considerations, Planning, Procedures,
and Checklists
TN-46/2013a**

Foreword

This technical note was developed and published with the technical help and financial support of the members of the Plastics Pipe Institute. The members have shown their interest in quality products by assisting independent standard-making and user organizations in the development of standards, and also by developing reports on an industry-wide basis to help engineers, code officials, specifying groups, and users.

This technical note has been prepared to provide those responsible for the maintenance of existing HDPE pipelines with suggested general guidelines for the repair of those lines that have been subjected to third party or other unforeseen damage. These guidelines constitute a set of basic operations that have been demonstrated by test and experience to produce satisfactory repairs with commercially available materials. Each specific procedure must be acceptable to, and qualified by, the operator having legal responsibility for the performance of the piping system. This document was not intended to provide system design information. Go to the PPI website at www.plasticpipe.org for different system design documents.

The Plastics Pipe Institute, Inc. has prepared this technical note as a service to the industry. The information in this report is offered in good faith and believed to be accurate at the time of its preparation, but is offered “as is” without any express or implied warranty, including WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. Additional information may be needed in some areas, especially with regard to unusual or special applications. Consult the manufacturer or material supplier for more detailed information. A list of member manufacturers is available from PPI. PPI does not endorse the proprietary products or processes of any manufacturer, and assumes no responsibility for compliance with applicable laws and regulations.

PPI intends to revise this report from time to time, in response to comments and suggestions from users of this note. Please send suggestions for improvements to PPI. Information on other publications can be obtained by contacting PPI directly or visiting the web site.

The Plastics Pipe Institute, Inc.
469-499-1044
<http://www.plasticpipe.org>

June 2013

GUIDANCE FOR FIELD HYDROSTATIC TESTING OF HIGH DENSITY POLYETHYLENE PRESSURE PIPELINES :

OWNER'S CONSIDERATIONS, PLANNING, PROCEDURES, AND CHECKLISTS

Purpose of Field Testing:

Hydrostatic testing is universally known and accepted as the primary means of demonstrating the fitness for service of a pressurized component. It is the responsibility of the owner, through its agents (engineer, contractor, or hydro-test company) to develop its own safe and appropriate hydro-test plan, taking into consideration all the elements presented in this and other reference documents, in order to access and accept the installed pipeline from the contractor. After hydrotest, a pipeline or pressure vessel component may usually be expected to safely contain its intended operating pressure. However, even after a successful hydro-test, leakage or forced ruptures may occur later, for a variety of other reasons. The pre-commissioning hydro-test is simply one tool for evaluating a pipeline. The purposes of hydrostatic field testing of polyethylene pressure pipes using water are several, including:

- To access the installed structural integrity of the pipeline for acceptability.
- To try to reveal the occurrence of faults or defects in the pipe laying procedures, as exemplified by damaged pipe or fusion joints non-conforming to the qualified fusion procedures.
- To try to reveal the occurrence of faults in the assembly procedures for pipeline components, as exemplified by tapping bands or saddles, flange sets, or Mechanical Joint assemblies.
- To try to validate that the pipeline will sustain an acceptable level of over-pressure slightly greater than its design pressure, without leakage.

Note: Field testing is not intended to supplement or replace product standard test requirements.

The factors which affect the hydro-testing of HDPE pipe during commissioning procedures are: the creep characteristics of the PE pipe, the percentage volume of trapped air in the pipeline, and temperature variations. The self-limiting creep expansion of HDPE pipe is normal behavior for plastic materials when an internal pressure is applied, and is not an indication of a leak.

History:

Polyethylene pipe is a lower modulus visco-elastic material that dilates in diameter (creep-strains) when subjected to higher stress during hydrotest. This means that for a fixed volume of clean fill water, the hydrostatic pressure will decline slightly during the test time, as the polyethylene molecular chains stretch and align under high stress. This pressure decline does not mean the polyethylene is leaking. It is a visco-elastic material parameter that requires adjustments to the hydrostatic test procedure as compared to rigid elastic metallic pipes. This effect is more noticeable in larger diameter HDPE pipes, due to the large mass of clean fill water. Alternately, to hold constant pressure, an additional volume of make-up water will be required to fill the expanded volume of the stretched pipe diameter. Neither of the above two observations means that a leak is present in the pipeline.

There are two test methods which can be used, depending upon the objectives of the test program. The easiest and quickest method suitable for all pipe diameters is the Modified Rebound Method originally developed by Lars-Eric Janson in the 1980's. As a similar alternate, ASTM F2164 instructs to fill and then thermally stabilize the pipeline with no air entrapment, pressurize the pipeline at test pressure for 4-hours, slightly reduce the pressure, and then observe the pressure for one hour to remain essentially constant (within 5% variation) to achieve an acceptable test. The Plastic Pipe Institute's **Handbook of Polyethylene Pipe** describes general hydrostatic testing, based on ASTM F2164. (www.plasticpipe.org/pdf/chapter02.pdf)

The concept behind hydro-testing is to strain the pipe, fittings and appurtenances. Any defects from manufacturing or flaws from construction are typically forced by stress intensification to reveal themselves by weeping, leaking, or rupture. Any remaining defects are considered sub-critical within a tolerable flaw size limit, and should remain stable thereafter at the lower operating pressures. Hydro-testing provides the normal level of assurance for leak integrity and the absence of flaws that exceed an intolerable flaw size. Generally speaking, the higher is the ratio of test pressure to actual operating pressure, the more effective is the test, within material stress limits.

Field Hydro-testing of Polyethylene Piping and Pipelines:

Hydrostatic pressure testing requires adopting an appropriate combination of method, pressure, time duration and length of test section. The test parameters and test details usually are determined with due consideration for the following:

- Pipe material
- Pipe diameter and working pressure rating
- Length of test section
- Duration of the test
- Magnitude of the test pressure and planned rate of pressurization
- Presence of air in the pipeline
- Potential movement of pipeline thrust restraints
- Limiting pressure for thrust and anchor supports
- Accuracy of test equipment
- Ambient temperature changes during testing (stability of the temperature)
- Presence of small leaks in hydrotest equipment or connections used
- Potential for leaks in the pipeline

Note: It is advisable to begin testing early during the pipeline installation to confirm adequacy of the fusion, laying, embedment procedures, and then later to progressively increase the length of test section, as experience is gained. Polyethylene pipe lengths as long as 1000 meters, or 3000 feet, have been commonly tested.

Definitions: (Refer to [Appendix B](#))

Selection of Test Pressure:

The pipeline operator or owner is responsible for approving the type of test, the length of test, and the test parameters, as recommended by qualified advisors to the owner/operator. The hydrostatic pressure test is a leak test intended to validate the integrity of the pipeline. The test pressure is never less than the designed operating pressure. The maximum hydrostatic test pressure is based on the pipeline component with the lowest design pressure rating. The hydrostatic test pressure is usually between 1.25 times the nominal operating pressure and 1.5 times the Design Pressure Rating of this component. The maximum hydrostatic test pressure must be recorded at the lowest point along the pipeline, and must be compensated for temperatures other than 73°F.

The ASME Code for Pressure Pipe, in B31.4, requires the hydro-test at 1.25 times the MAOP (maximum allowable operating pressure) for steel pipe. Typically, for ductile, visco-elastic HDPE pipe, the hoop-stress during hydro-test should exceed 30% of the specified minimum yield stress (SMYS) but remain less than 42% of the SYMS. The following test pressure ratios for HDPE pipe may be used, as decided by the pipeline owner, depending upon the owner's needs and test objectives.

1.0 x Operating or Design Pressure

1.25 x Operating or Design Pressure

1.50 x Operating or Design Pressure

For example:

1.00x Design Pressure Rating for PE4710	(1000-psi pipe hoop-stress)
1.25 x Design Pressure Rating fro PE4710	(1250-psi pipe hoop-stress)
1.50 x Design Pressure Rating for PE4710	(1500-psi pipe hoop-stress)

The hydrostatic test pressure is a short-term test. The short-term tests for polyethylene pipe use the short-term strength (eg: stress intensity) of HDPE.

HDPE Material	HDS@73°F	Multiplier	Test Pressure Hoop-Stress
PE3608	800-psi	1.50	1200-psi (75%HDB)
PE4710	1000-psi	1.25	1250-psi (78%HDB)
PE4710	1000-psi	1.50	1500-psi (94%HDB)

Stress within straight pipe is simple, but stress in fittings is more complex. Within elbows, tees and wyes, the local stress intensifications can raise the local stress to higher stress values, unless the fabricated fittings are sufficiently wall thickened to compensate for geometric effects. The design pressure ratings of installed fittings should be recorded prior to hydro-test, and, the test pressure should be based on a multiplier times the pressure rating of the pipeline component with the lowest pressure rating in the test section at its elevation in the test section at the test temperature.

Many owners opt for intermediate test pressures giving hoop-stress intensities above 1000-psi hoop-stress. Again, the maximum hydrostatic test pressure is based on the pipeline component with the lowest design pressure rating. The hydrostatic test pressure is usually between 1.25 times the nominal operating pressure and 1.5 times the Design Pressure Rating of this component. The maximum hydrostatic test pressure must be recorded at the lowest point along the pipeline (or compensated for by water elevation head to a different point in the pipeline), and must be compensated for temperatures other than 73°F.

Three hydro-test parameters are: the hydrostatic test pressure, ratio of hydrostatic test pressure to actual operating pressure, and the pipe's estimated hoop-stress during test. These should be calculated and recorded as follows:

$$\text{Hydro-test Pressure} = \text{_____psi (approved by Authorizing Agent(s))} \quad \text{EQ-1}$$

$$R = \text{hydro-test pressure} / \text{operating pressure} \quad \text{EQ-2}$$

$$\text{Estimated pipe hoop-stress} = (\text{hydro-test pressure} \times (\text{DR}-1)) / 2 \quad \text{EQ-3}$$

Selection of Test Section Lengths:

The pipeline length tested shall be either the whole pipeline, or a section of the entire pipeline capable of being isolated, dependent upon the length and diameter, the availability of water, the disposability of the water, and the spacing between sectioning valves or blind flanged ends. Based upon elevations and distance, the pipeline shall be divided into test sections such that:

1. The hydrostatic test pressure at any point in the test section is (i) not less than the design pressure, and, (ii) not more than 25% to 50% above the design pressure rating of any pipeline component; and
2. Water is available for the test together with facilities for its disposal, in accordance with regulatory requirements, after test.

When the pipeline is longer than 3000-feet, the pipeline may need to be tested in several sections. Where long lengths are tested, radio, cell phone, or other communication means may be required between test operators for safety, to coordinate test activities and keep the test within desired time limits.

Very long test sections may incorporate a large number of mechanical and flanged connections, which must be checked for leakage. The longer the test section becomes, the harder it is to locate a leak or to discriminate between a leak and other effects such as entrapped air being dissolved into solution under pressure. Prior to testing execution, a pre-assessment should be made as to what the recorded pressure versus time curves should look like, and how to read or interpret the actual recorded pressure data, so that acceptance or corrective action can be taken by experienced, trained, and qualified operators.

Selection of Fill-Rate:

Slowly fill the test section of the pipeline with water at ambient temperature. Filling is ideally supplied from the lowest point such that the water's entry is submerged and under a "pool" of water inside the pipeline, thus avoiding frothing, air entrainment and air being dissolved into the test water. A slow, submerged, fill velocity will prevent air entrainment and dissolving when the water stream is cascading through downward slopes along the pipeline. Dissolved air can be eruptive leading to a large surge pressure event, and can disguise a possible leak. Obviously the high point air vents should be open and monitored. After filling, allow 3-hours to 24-hours for the system to reach thermal equilibrium, AND, to allow time for any dissolved air to "breathe" and exit the system vents. The period of stabilization will depend upon the volume of water within the pipeline. The recommended slow fill-rate Q, in gpm, is based on the pipe inside diameter D, in inches, and an axial filling velocity of less than 10-feet per min calculated as follows:

$$Q_{\text{gpm}} = 0.402 D^2_{\text{inches}}$$

A firm urethane foam pig or swab, pushed by the fill water, may be used to assist in air removal, especially where the pipeline undulates and air pockets may be trapped.

Pre-Testing Checklist :

- Prior to carrying out any testing activities, many precautions and considerations must be addressed.
- **THE PLASTIC PIPE INSTITUTE MAKES NO CLAIMS THAT THE LIST BELOW IS COMPREHENSIVE. THERE ARE OTHER CONSIDERATIONS FOR EACH PROJECT. EACH PIPELINE OWNER MUST DO ITS OWN DUE-DILLIGENCE TO COMPILE ITS OWN COMPREHENSIVE HYDROTEST MANUAL, PRE-TEST CHECKLIST, TEST PROCEDURES, AND ACCEPTANCE CRITERIA.**

TEST PLANNING

- Has all the pipeline construction been completed, inspected and signed off?
- Has it been verified by QA/QC that the proper pipe material, diameters, DR's, flange ratings, fittings ratings, are in accordance with the drawings and specifications?
- Has the last fusion joint been allowed to cool sufficiently to ambient temperature?
- Has the pipeline been cleaned of all construction debris and foreign matter?
- Are the facilities available for preparations for testing?
- Have local authorities/ citizens been notified of the intent to conduct hydro-testing?
- Are all foreign construction materials removed from the trench in contact with the HDPE pipe?
- Are there any point loads on any fittings? (remove them)
- Are the PE pipelines supported by backfill or otherwise restrained by sandbags to prevent lateral movement or axial contraction under test pressure?
- Where cast concrete has been used, has the concrete cured in excess of 7-days?
- Will the hydro-test be scheduled to occur in dry weather, so that leaks may be detected? (testing in wet weather or in water filled trenches is not recommended)
- Have the proper environmental and regulatory permits been obtained for access to sufficient volumes of fill water, post-test water analysis and treatment, and proper disposal of the test water?
- Has the pipeline elevation profile and filling procedure been analyzed for the fill velocity potential against dynamic surge pressure during filling, which might over-pressure local components, especially in low elevations?
- Has the volumetric rate of fill, fill method, and fill procedure been finalized?
- Has the rate of initial pressurization, prior to full pressure hydro-test, been finalized?
- Has the test plan manual been approved, circulated to all operators, and understood by all participants in pre-test safety and quality meeting? (sign-in sheet)
- Are some bolted joints going to be left exposed for visual inspection and possible re-torquing during or after testing?
- If desired, is compacted embedment and trench fill going to be placed so that certain specified joints, fittings, service connections, or valves are exposed, in accordance with the owners test plan?
- Have all high elevation points and lateral "dead-legs" been identified with provisions made to properly install adequately sized air vent valves of sufficient volume & pressure capacity? Has it been verified that all vent points are installed in the "open" position, for proper operation during filling? Blind-flanges may be used as high-point vents when they are snugly bolted and subjected to low filling pressure, such that trapped air is pushed out past the snug gasket, until the fill-water reaches it and sprays out, thus indicating that all air is expelled, followed by the mechanic fully torquing the flange per the approved bolting procedure with just static head against the blind.
- Has an emergency response plan been considered (as appropriate) in the event of a dramatic rupture during hydro-test?

- Has a temporary, foam pipe-pig launcher and receiver been considered so as to make filling the pipeline easy, and to prevent entrapped “pockets” of air?
- Has the Hydro-testing Schedule and Milestone plan been fully developed, reviewed approved, understood and implemented?
- Has the contractor’s list been published of nominated personnel who are to supervise the pressure testing operation, including their qualifications, tasks, and responsibilities, and limits of authority?
- Are supporting documents such as P&ID and isometric drawings available for the hydro-test section, which conform to the as-built configuration?

EQUIPMENT

- Are all blind-flanged ends (blanks) and valves restrained and supported?
- Are all intermediate valves open and capable of passing or venting entrapped air?
- Has all the equipment been reviewed for capacity to perform its function without fault during the test?
- Have all gages, dead-weight testers, data recorders, temperature recorders, water volume meters, etc, been calibrated within the last year; are certificates on file? Are the gages permanently identified with traceability to calibration records?
- Are at least two calibrated pressure gages or instruments placed into the test system to be used as a cross-check for gage accuracy? Typically, one calibrated pressure gage is placed at each end and then monitored, to assure the entire test section was pressurized. When an additional dead-weight tester is used, the pressure readings shall be recorded at a minimum of ½-hour increments. When a calibrated pressure recorder is used, it shall record continuously during the test. Any pressure gage used shall have sufficient pressure range to 150% of the maximum allowable test pressure.
- Are all temporary tools such as hoses, connection fittings, flanges, blinds, isolation valves, etc, rated higher than the maximum hydrostatic pressure?
- Is an adequately sized and calibrated hydro-test Safety Relief Valve installed and checked for proper operation; and, set for 5 psi higher than the maximum test pressure expected at its point of installation?
- Are properly sized drain ports correctly installed at the lower position along the pipeline, so as to enable emptying of the pipeline as required by contract specifications? Have provisions been made for treatment and disposal of the hydro-test water? Note: when draining is started, have provisions been made to open the upper air vents, to avoid a vacuum internal to the pipeline and to facilitate speed of draining?
- Are the test heads restrained? Blind flanges are fully restrained. Mechanical ends that are not end load resistant shall be temporarily strutted or anchored to withstand the test pressure thrust without movement. Temporary supports shall not be removed until the pipeline is de-pressurized and shall have signs noting the load limits on temporary fittings and supports.
- Does the hydrostatic pressurizing pump have its own calibrated safety relief valve?
- Has the pressurizing equipment been placed in the proper position and checked for proper operation without leakage?
- Is the pressurization pump “right-sized”? Too small of a pump will extend the test duration, and too large of a pump may inhibit adequate control of the test pressure.

SAFETY

- Has there been a safety meeting to review the safety measures and safe practices that are being employed?
- Will test operators be supplied radio or cell phone communications so that the test progress at remote, non line-of-sight sections can be monitored for venting, or possible leaks or other problems?
- Has a safety perimeter or boundary been established along the pipeline, surrounded or marked by posts supporting yellow safety-tape or safety-line, to assure unnecessary personnel and equipment stay out of the area during pressurized testing?
- Have the on-site hydro-testing personnel filed their OQ (operator qualifications) validating that they have experience and training (contractor licenses, professional degrees, professional certifications, work history) to participate and perform hydro-testing activities, plot pressure-time curves, make calculations, and otherwise work in their assigned role during the hydro-test, in a safe and knowledgeable manner?

- Have all personnel authorized to participate in the hydro-test, been adequately instructed in the test plan, and have they been issued the required personal protective equipment?
- Inclusion Zone: Has the access to the test ROW or test zone been limited to only those trained and qualified persons who are necessary to perform the test?
- Exclusion Zone: Has a safety perimeter or boundary been established along the pipeline, surrounded or marked by posts supporting yellow safety-tape or safety-line, to assure un-necessary personnel and equipment stay out of the area during pressurized testing? (Note: During testing or de-watering, there are possible unrecognized hazards that may not have been completely controlled, such as unexpectedly high pressures from internal malfunctions or equipment failures, rupture of the pipe or fusion joint, un-detected flaws. Such situations may develop forces large than the designed capacities of the anchorages. All non-essential persons should be excluded from the test zone.)

TESTING

- Is testing going to be conducted against a closed valve? Testing should not be conducted against closed valves unless they are mechanically restrained and it is possible to check for leakage past the valve seat. Best practice is to blind-flange before the closed valve.
- Have provisions been made to remove all trapped air at high points? In non-accessible zones, high velocity water flushing can laterally “move” the air from those zones if the water velocity exceeds about 2 to 4 feet per second. This may take large volumes of water and large pumps, but can be effective to move the air bubble to a vent location, when repeated a few times. The methods of removing trapped air are pigging, flushing, venting.
- Has removal or isolation been accomplished on all monitoring pressure-gages, control-valves, relief valves, rupture disks, orifice plates, diaphragm instruments, expansion joints, compressors, lower pressure pumps, etc , which could be damaged during the high pressure test?
- Have the proper drain ports of adequate size been installed correctly in the specified low-elevation points to permit draining of each zone of the hydro-test section?
- Will the fill rate be controlled to at or less than 10-feet per minute axial velocity? This fill velocity avoids air entrainment when the filling water is cascading through downwards gradients along the pipeline (hence preventing the potential eruption of dissolved air like that occurring from a shaken bottle of soda water.)
- Has it been verified that proper tags, tag-outs, signs, and notifications have been implemented/ applied/installed?
- Has it been verified that check-valves (CV) are not being pressurized against the flapper/ seat? When the pipeline has check-valves, assure the CV does not block the flow of the water to other pipe sections included in the test (remove the CV flapper, or block the CV flapper in the “open” position.)

POST-TESTING

- Have the temporary de-watering lines been secured against movement or de-coupling? Note: During de-watering, significant and sudden pressure variations will occur within the mainline and be transferred into the temporary de-waterline lines. These variations can be caused by changes in pig velocity thru bends, or, changes in pig and water velocity due to changes in pipeline elevation. Also, air by-passing the pig combining with entrapped air can accumulate stored energy. These sudden changes produce instant over-pressure surges transferred into the temporary de-watering lines which can result in movement, rupture, or de-coupling of those lines. These violent reactions can damage equipment, cause bodily harm, and have killed workers, when the temporary lines were not properly anchored and coupled. The project safety analysis should include safe-guards against lack of anchoring, worn coupling, and excessive and variable system pressures; and for installed anchoring, restraint, and control of de-watering piping, written procedures, and adequate employee training. Pipeline operators are required to protect employees and the public during hydro-testing: 49 CFR 192.515(a) states that: “each operator shall insure that every reasonable precaution is taken to protect its employees and the general public during testing.”
- Have the Hydrotest Data, record types, and final Report Forms and format been prepared and approved for use?

The Hydro-Test Method:

The Test Method Evolution:

In the USA, in the 1980's and 90's, the prevailing hydro-test method was presented in the Plastic Pipe Institute **Technical Report # 31** (TR-31), which described a constant pressure test method, with allowable make-up water volumes to compensate for the diameter creep strain of the viscoelastic HDPE pipe. Out-of-Print copies of PPI TR-31 are available from www.plasticpipe.org.

The prevailing hydro-test method used in the USA today is **ASTM F2164: "Standard Practice for Field Leak Testing of Polyethylene Pressure Pipe Systems Using Hydrostatic Pressure."** It is essentially a hydrostatic "pressure rebound method". This standard practice is available for purchase at: www.astm.org. The derivation of the "Pressure Rebound Method" is given in Appendix "A" to this document.

In summary, the pressure rebound method is a world-wide accepted method for testing HDPE pipes for integrity of all pipe, joints, and components.

The Method: The Pressure Rebound Test procedure includes three phases.

Preliminary: Phase I:

- Fill and vent and purge the pipe system of trapped air to less than 4% trapped air by volume. (This can be validated, as will be described later.) The pipeline shall be full of water, but not positively pressurized (other than the natural hydrostatic head) for 60-minutes prior to the start of the re-bound hydro-test.
- Start the test timer at T= "zero" minutes. Rapidly pressurize the test section to the specified test pressure (**STP**) in less than 10 minutes, if possible. Hold the STP for 30 minutes by repetitively injecting small volumes of make-up water into the test section to sustain, but not exceed, the STP, as the HDPE molecules creep-strain and "stretch", as the pipe slightly expands. Inspect exposed joints and connections for visible leaks during this time period.
- At T= 30 minutes, valve-off and isolate and record the confined specified test pressure (STP) as P₃₀. Allow the test pressure to decay for an additional 60 minutes, until the timer is T= 90minutes.
- Measure and record the residual test pressure as P₉₀ at T= 90 minutes.
- If P₉₀ > 70% of STP, this phase has passed and proceed to Phase II.
If P₉₀ is ≤ 70% of STP, then the test has failed, either because of a leak or because of excessive trapped air dissolving into the water.

Secondary: Phase II: Air Volume Assessment

If any trapped air or dissolved air content is "low" compared to the water volume filling the pipe system, then the pressure drop should be fairly linear upon a quick release of a partial volume of water from the pipeline. If the dissolved air or trapped air content is "high", then, even though a small volume of test water is quickly released, the test pressure will not drop much because the air will expand to fill the space.

In this phase, the P₉₀ test pressure is reduced, per the instructions below, by bleeding out a small volume of pressurized test water, and, the volume of water that is bled out is measured by a calibrated meter or by measuring receptacles (gallons, buckets, barrels).

- The Air Volume Assessment is performed as follows:
 1. Quickly (< 5minutes) and safely bleed out water from the pipeline so as to reduce the pressure by 10% to 15%. Accurately measure and record the pressure drop as **ΔP**.
 2. Accurately and safely measure and record the water volume bled out as **ΔV**.
 3. Calculate: **ΔV_{max allowable} = 1.2 V ΔP { (1/ E_w) + (D / t E_R) } = ___ gallons.**

Where:	1.2	=	air allowance factor.
	V	=	test pipe section volume of water, in gallons.
	ΔP	=	measured pressure drop, in "psi".
	t	=	nominal pipe wall thickness, in inches.
	D	=	pipe inside diameter, in inches.
	E _w	=	Bulk modulus of water, in psi (from chart below).
	E _R	=	HDPE pipe modulus, in psi (from chart below).

Bulk Modulus of Water, E_w . (The resistance to volume change when subjected to pressure)

Temperature	Bulk Modulus
5°C – 41°F	301,600-psi
10°C – 50°F	306,000-psi
15°C – 60°F	310,400-psi
20°C – 68°F	314,750-psi
25°C – 77°F	320,500-psi
30°C- 86° F	323,450-psi

HDPE Pipe-Grade Material Modulus, E_R

Temperature	1-hour test	2-hour test	3-hour test
5°C – 41°F	143,600-psi	134,900-psi	130,500-psi
10°C – 50°F	130,500-psi	123,300-psi	118,900-psi
15°C – 60°F	118,900-psi	113,150-psi	108,800-psi
20°C – 68°F	108,800-psi	103,000-psi	98,630-psi
25°C – 77°F	100,080-psi	94,275-psi	91,375-psi
30°C -- 86°F	92,825-psi	88,475-psi	87,024-psi

- When $\Delta V \leq \Delta V_{\max \text{ allowable}}$, Phase II passes; proceed to the main test, Phase III.
- If $\Delta V > \Delta V_{\max \text{ allowable}}$, **the test has failed**, and the cause must be corrected. Upon correction, the preliminary and secondary phases are to be repeated until passing.
- When excessive air is entrained or trapped in the pipeline, the pressure response is increasingly non-linear. The above air assessment test validates that minimal air is trapped and the test result will be indicative of the leak integrity of the pipeline, as illustrated in AS/NSZ Standard 2566-2 Appendix M and WRC's IGN 4-01-03 :

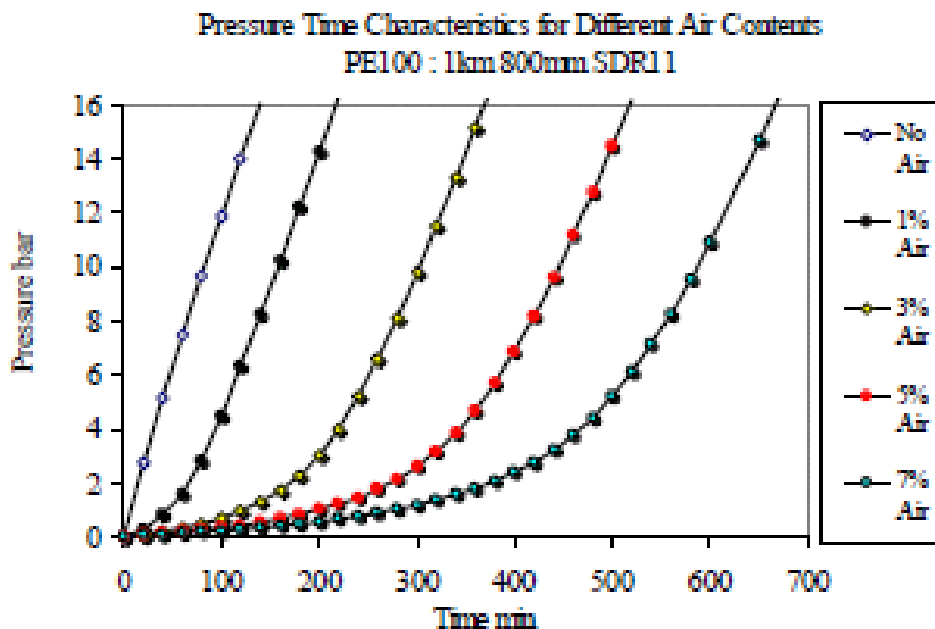


Figure A2.1: Pressure Rise Characteristics for 1 km of 800mm SDR 11 PE 100 Pipe

Final: Phase III

After the pressure was dropped about 10% to 15%, and while the above air assessment calculations are being made, the pressure internal to the HDPE pipe should stabilize and remain constant within +/- 5% of the Phase III reduced test pressure. Because the HDPE pipe molecules have been "stretched" during the preliminary "expansion" phase, upon lowering the water test pressure, the molecules will elastically work to revert to their original length, and hence should compress the final

test volume of water causing the final Phase III test pressure to “rebound” and rise slightly. This is a natural effect from visco-elastic HDPE material. If the plot of re-bound pressure versus time shows a continuous falling of pressure, the pipeline is leaking and the test fails. Ordinarily, the Phase III rebound test time is 30-minutes. In some cases this test duration may be extended to one-hour. If the Phase III observation test duration is extended to 90-minutes, the initial pressure-rise may be followed by a flat stable pressure followed by a slight drop as visco-elastic creep resumes later in this extended period. The standard Phase III observation and approval period is 30-minutes per European Hydro-test Standards, with a possible extension to one hour per ASTM F2164 , if required for all observations along the pipeline length. The test shall not be acceptable when there is a failure of any pipeline component, or any measurable or visible leakage. The test shall be acceptable when the Phase III reduced pressure rebounds or remains static for 30-minutes. If the hydro-test fails, the cause should be corrected and a full procedure re-test conducted after a suitable “rest and relaxation” period, prior to the re-test. The typical chart below, from AS/NZS 2566-2 Appendix M, illustrates a typical successful hydro-test:

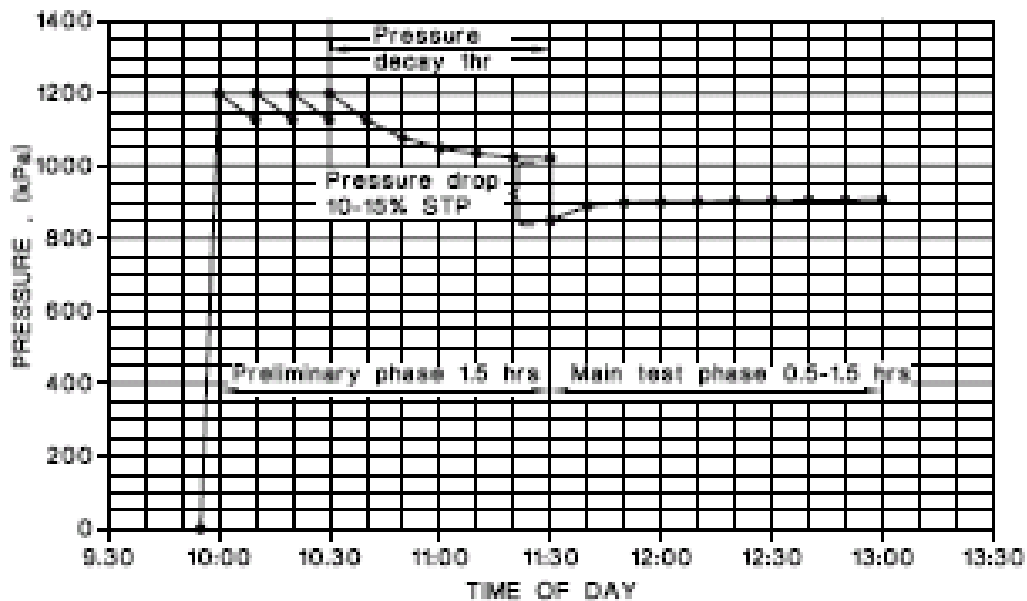


FIGURE M5 TYPICAL SUCCESSFUL MODIFIED REBOUND TEST FOR A PE PIPELINE

Reproduced with Permission from SAI Global Ltd under License 1301-c052
 Source : AS/NZS 2566-2, Appendix M
www.saiglobal.com

De-Pressurizing, and Draining the Test Section:

After the hydro-test has been successfully completed, the elevated pressure within the test section is to be safely reduced in accordance with the test plan. When the test section is ready to be drained, the air vents specified shall be opened and the water drained from low points, at a flow-rate in accordance with the test plan. The hydro-test water shall be re-used, treated, or drained to an approved water-way, after-which all connections shall be closed or otherwise re-instated. Remove all temporary blinds, supports, test connections.

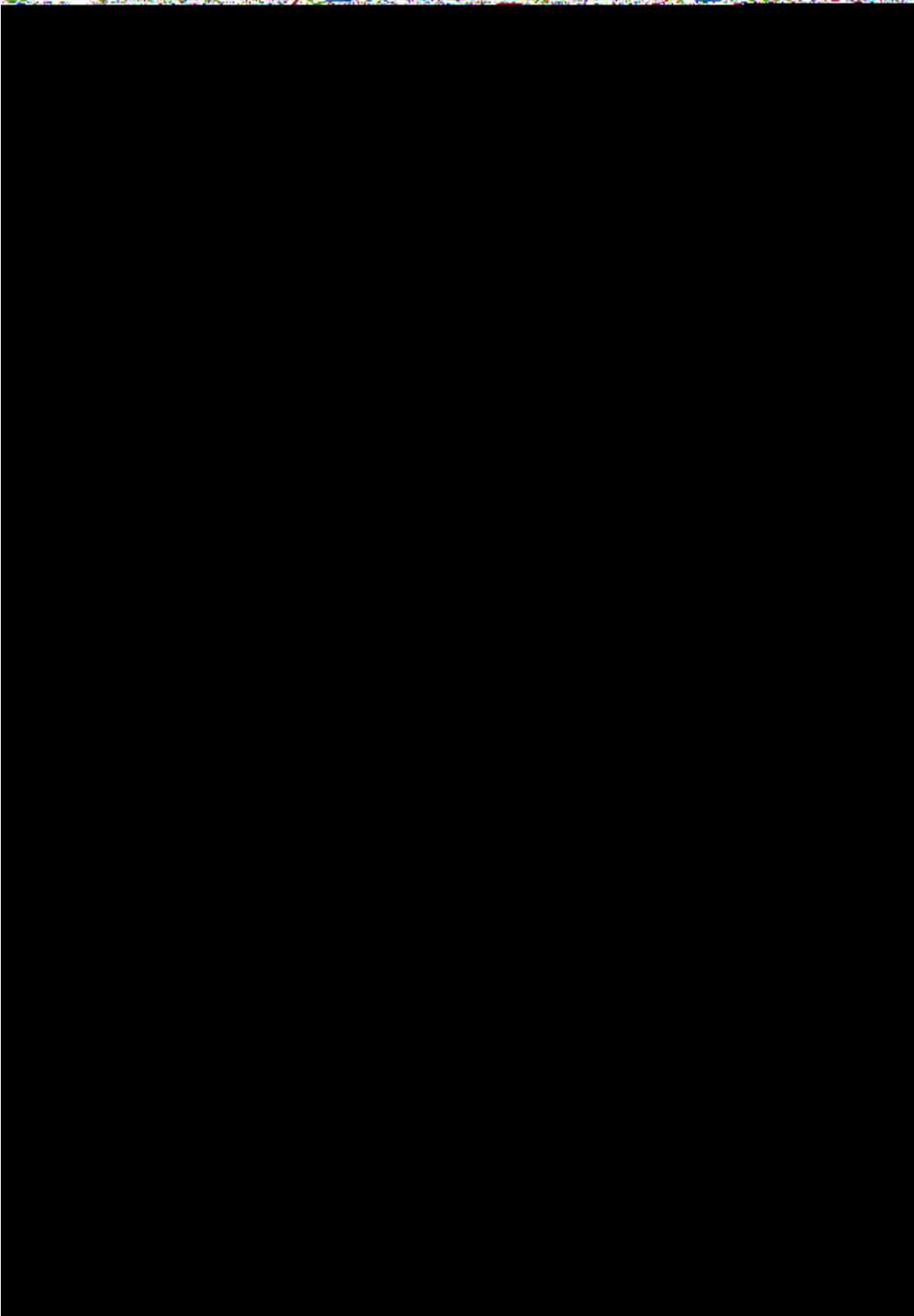
The Test Report:

The pressure test report should include full details of all work associated with the hydro-test, including the planning documentation, safety training, pre-test meeting minutes, the hydro-test-plan, the hydro-test documentation, any leak corrective actions, the certified test results, and the sign-offs for acceptance.

Items also to be included are:

- Pipeline test section length versus elevation chart showing heights of air vent valves, gage locations, filling and drain points, pressure rating of the pipe and pressure rating of all fittings and appurtenances included in the test.
- Notations of leakage, failure, or rupture of any thrust blocking, pipe, fitting, joint, connection, etc.
- Location and nature of any leaks that were repaired.
- Test Water temperature and ambient temperature.
- Plot of test pressure variation by test time duration for each phase.
- The plot of the pressure decay graph & its interpretation; explanation of variances.
- All calculations for Phase I, Phase II, and Phase III.
- Verification of visible inspection of any exposed pipeline components.
- Date and times of the hydro-testing; gage and instrument calibration records.
- Reference Standards used as guidelines for the hydro-testing.
- Signature acceptance of hydro-test results by: test contractor, owner, principal contractor.

Note: A typical re-bound test report, with signatures, is illustrated on the next page.



Reminder: The following elements are identified as contributing factors to variation in the pressure test results, and should be considered when interpreting the test data:

- Length of the test section
- Diameter of the pipe
- Measurable temperature changes
- The range of the test pressure imposed on the test section
- The rate of pressurization
- The presence of some air in the pipeline
- Relative movement or slippage of mechanical fittings
- The stiffness and compaction of the soil around the pipe to resist pipe expansion
- The accuracy of the testing apparatus.

Commissioning:

The hydrostatically proven pipeline shall be commissioned for operation following the written standard start-up procedures and practices adopted or instituted by the local authority, or owner, or the owner’s representative.

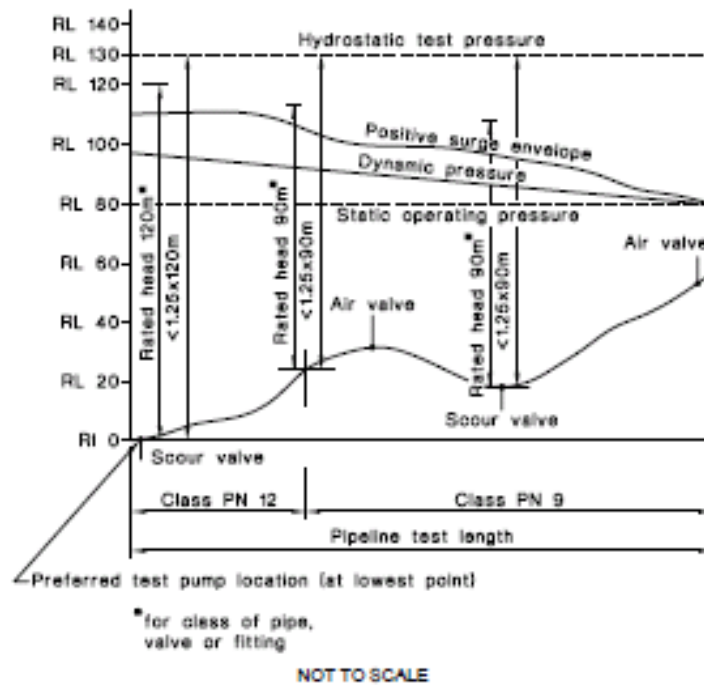


FIGURE M1 TYPICAL PRESSURE PIPELINE UNDER FIELD HYDROSTATIC TEST

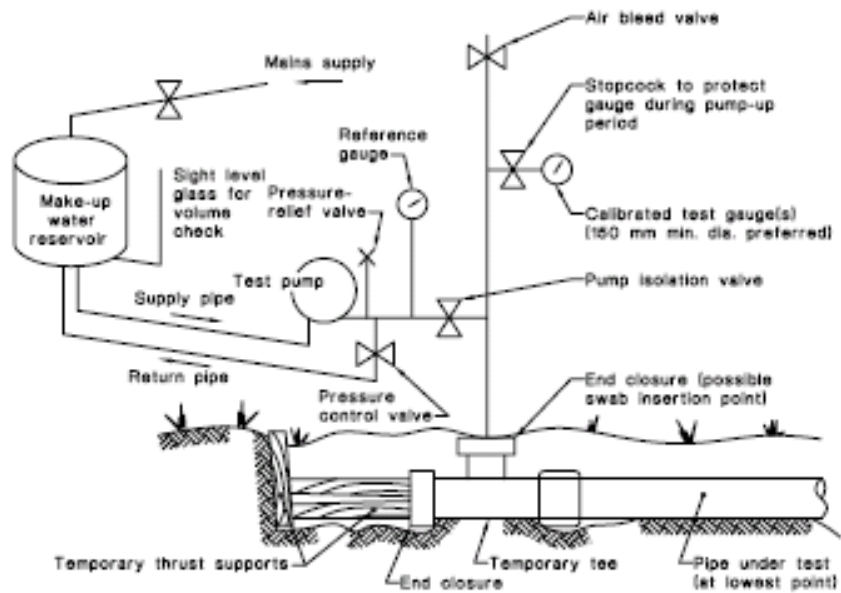


FIGURE M2 TYPICAL FIELD PRESSURE TEST EQUIPMENT LAYOUT

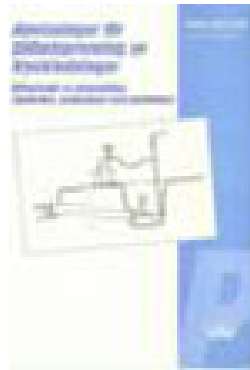
Reproduced with Permission from SAI Global Ltd under License 1301-c052
 Source : AS/NZS 2566-2, Appendix M
www.saiglobal.com

APPENDIX A – DERIVATION OF THE PRESSURE REBOUND METHOD

The original pressure rebound method was developed and proven by Dr. Lars-Eric Janson in the 1990's. Svensk Vatten of Sweden published an extensive report on the procedure and technology in 1997, as VAV Project #78, "P78", titled "Anvisningar för täthetsprovning av tryckledningar tillverkade av polyolefiner (PE, PP och PB)".

It can be found at : VAV Publication P78, Svenskt Vattens Vattenbokhandel:
<http://www.svenskvatten.se/> ; search the Vatten Book Publications for "P78".

Additional guidance on P78 is offered at:
http://www.svenskvatten.se/Documents/Kategorier/SVU/Rapporter/SVU-Rapport_2011-10.pdf



Additionally, The British Water Research Center, WRc, published a simplified version in its "Guide to the Pressure Testing of Water Supply Pipelines and Sewer Rising Mains", 1999, which is contained within in the "WRc Polyethylene Pipe Systems Manual", 2002 (3rd edition). It also published extensive guidance on the practical use, and the limits of use, of the pressure rebound method at:

<http://www.water.org.uk/home/member-services/wis-and-ign/current-documents/ign-4-01-03-v2-march-2011.pdf>

Also, the British Standards community of pipe manufacturers published BS **EN805:2000**: "Water Supply: Requirements for Systems and Components Outside Buildings". This standard hydro-testing practice outlines a similar pressure re-bound method. It is available from:

<http://shop.bsigroup.com/en/ProductDetail/?pid=000000000019983094>

The Australian hydro-test pressure rebound method is further described in their standard:

AS/NZS 2566.2: including Appendix M, available from: www.standards.com.au

Additional notes on hydro-testing are available from: <http://www.pipa.com.au/images/pdf/TP005.pdf>

APPENDIX B – DEFINITIONS

Design Pressure Rating: the pressure the polyethylene pipe is engineered to sustain indefinitely at 73F, without concern for pressure rupture. This pressure capability is based on the hydrostatic design stress (HDS) of the material and the pipe dimension ratio (DR).

Design Pressure: the nominal operating pressure at which the pipeline is designed to function continuously. It is usually at or less than the design pressure rating.

Hydrostatic Test Procedure Manual : the written test plan manual with instructions and checklists by which the hydrostatic testing will be conducted in conformance with the owner's requirements for equipment, methods and procedures, data analysis, and basis for acceptance and approval of the hydro-test prior to pipeline commissioning. The test procedures to be adopted will vary with individual pipelines and the requirements outlined in the contract documents.

Independent Hydrostatic Testing Firm: a qualified and experienced business or corporation (usually unrelated to the pipeline construction company), which conducts pipeline hydrostatic testing as a regular function of its business, using experienced employees or operators certified by the company as qualified to conduct hydrostatic testing. The role of the independent hydro-testing company's designated representative is to witness the pressure test for the prescribed time, ascertain the extent of the test, record the necessary data, and forward the results and data package, as required, to the prime contractor, or engineer, or owner. The representative does not approve the "test"; the pipeline owner or operator must verify, approve, and certify the "test".

Polyethylene Hydrostatic Pressure Testing : Hydrostatic pressure testing (or 'hydro- testing') is a non-destructive method of testing the integrity of newly constructed or modified HDPE pipelines by temporarily filling the test section with a liquid, usually water, and then the pressure of the liquid is raised to a specified maximum pressure, compensated for temperatures higher than 73°F and measured at the lowest point in the pipeline (or compensated by water elevation head to a different point in the pipeline) which is maintained for a specified period of time. Any ruptures or leaks revealed during the test must be repaired or closed, and the test repeated, after a delay for elastic recovery, until no problems are noted.

Hydrostatic Pressure Testing Manager/Operator/Engineer: the person, qualified by experience or training, in overall charge of conducting the hydro-test of the subject pipeline. This person may be a contracted Independent Hydrostatic Testing Firm employee, or, a person nominated or approved by the pipeline owner-operator as its management representative, subject to review of the person's credentials.

Jurisdictional Authority : the individual, organization, office, governmental agency or official, authorized engineer, owner, or designated agent having the responsibility for approving or accepting procedures, equipment, or installations.

Designated Agent : The owner, engineering firm, hydro-test subcontractor, and the prime contractor may each have a designated individual authorized to review procedures, equipment, test data, etc..., and, for their respective parties, to approve by signature all test plan manuals, procedures, checklists, data, etc.