TECHNICAL BULLETIN: RCP IN HDPE PIPES

POLINTER

1. Introduction

Polyethylene is the main material used in pipe applications for gas and water transport. Gas companies prefer the installation of high-density polyethylene pipes that handle high pressures and large diameters instead of steel pipes, primarily because of their flexibility, ease of installation, long-term durability, not corrosion and relatively lower costs. . However, pipes made with this material occasionally have failures caused by direct impacts on the laying, resulting in the appearance of cracks that propagate at speeds of up to 200 meters per second along the pressurized line of the pipe, causing catastrophic damage[5].

The failure described is known as RCP (Rapid Crack Propagation) or rapid crack growth. Polyethylene, being a ductile and semi-crystalline plastic material, is not susceptible to rapid crack propagation, however, the need to use higher pressures (12 bar or 180 psig) and larger diameters (up to 760 millimeters) mean that the characteristic of resistance to crack propagation becomes important.

RCP failures can be initiated at pressures well below the design stress of the pipe, if the conditions to which it is exposed promote it. For example, a pipe made with a PE-100 type resin, whose long-term stress is around 10 MPa, can fail at lower stresses, if the temperature of use is low enough. That is why the manufacturers of pipes must design this systems4 under the worst conditions possible, in such a way to avoid RCP.

These circumstances have led to the development of test methods that allow the recording of the performance of this property in plastic pipes, among them are the FS method ("Full Scale" or real scale) and S4 (small scale in stationary state), which They allow to detect the pressure and temperature conditions at which an impact crack begins to propagate.

However, the causes associated with failures due to RCP of HDPE pipes depend on several factors, among the most outstanding are:

- Pipe geometry (dimensions).
- Internal pressure.
- Operating temperature.
- Material resistance properties to RCP.
- Pipeline processing.

Typical failure shapes are associated with the appearance of a wavy crack along the length of the pipe.

The crack is usually accompanied by marks in the form of "feathers" on the surface of the tube, in the direction of propagation. Crack bifurcations can also occur, traveling parallel to the main crack.

2. Test methods

Full Scale FS (Full Scale) method: considered the most reliable method, it is described in the ISO 13478 standard, and uses samples from tubes 18 meters long and up to 500 millimeters in diameter. However, its implementation is extremely elaborate and very expensive.

Figure 1 shows a diagram of the installation of the test equipment for CPR according to the FS method[3].

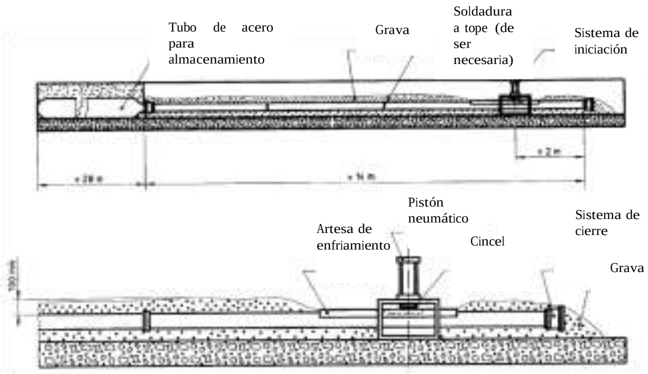

Figure 1: Installation for FS test

Reduced-scale method S42: developed as an alternative to minimize the investment costs of the FS method and to be able to establish a correlation with it. It uses much smaller tube samples and a series of baffles, described in ISO 13477.

Figure 2 shows a typical installation for the measurement of RCP on a reduced scale.

Figure 2. Equipo de RCP de escala reducida S4

Key results: Whether a test is conducted using the full scale FS method or the reduced scale S4 method, there are two key results used by the pipeline industry: critical pressure and critical temperature.

a) **The critical pressure:** it is obtained by carrying out a series of tests at a constant temperature (usually 0°C) and varying the internal pressure. At low pressures, where there is insufficient energy to drive the crack, as soon as it starts, it stops. At higher pressures, the crack propagates to the end of the tube. Critical pressure is the transition between the arrested crack at low pressures and the propagation at high pressures (see Figure 3).

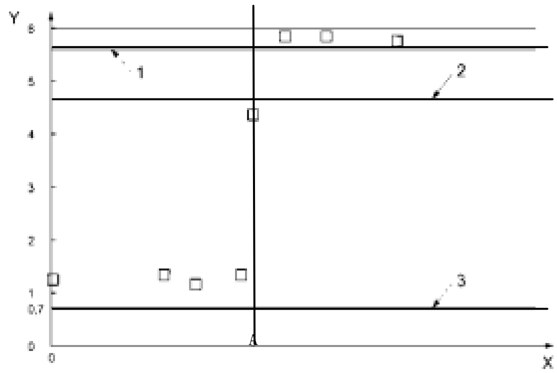

Figure 3. Typical graph of the RCP test at constant temperature.

X= Test pressure (bar or psi)
Y= Crack length/nominal diameter
A= Critical pressure (bar or psi)
1= Minimum test length
2= Critical crack length
3= Minimum valid crack length

b) **The critical temperature:** it is obtained by carrying out a series of tests at constant pressure and varying the temperature. At low temperatures (sub-zero range for HDPE), the material is brittle enough to resist crack propagation. At higher temperatures the crack stops and hardly propagates beyond the impact length given by the blade. The point Tc of Figure 4 indicates the critical temperature at which the crack length induced by the impact of the blade stops propagating (stops) due to the effect of the increase in temperature, observing a transition that defines this value.

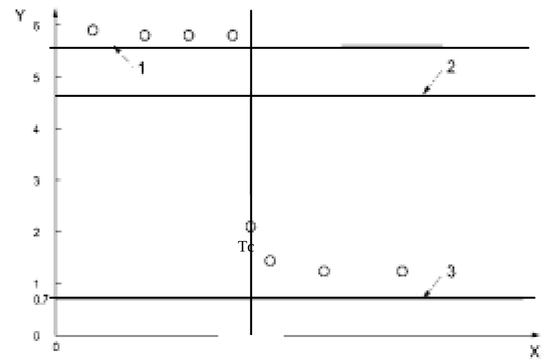

Figure 4. Typical graph of the RCP test at constant pressure.

X= Test temperature (°C)
Y= Crack length/nominal diameter
Tc= Critical temperature (°C)
1= Minimum test length
2= Critical crack length
3= Minimum valid crack length

Based on the above, a RCP event is possible if:

- A piping system is operating below critical temperature, or
- A piping system is operating; it is tested, above the critical pressure.

Figure 5 illustrates the zones where RCP may or may not occur in a pipeline, depending on the conditions to which it is exposed.[7]

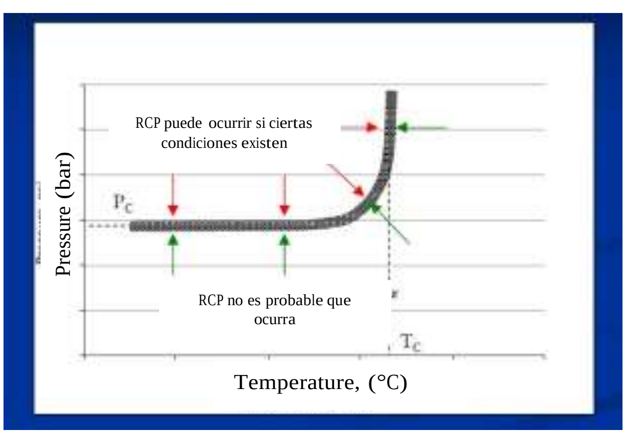

Figure 5. Critical pressure and critical temperature graph, with potential RCP zones

3. Types of Polyethylene

The S4 reduced-scale method has allowed comparative studies of RCP resistance between unimodal (single reactor) and bimodal (two reactors) polyethylene resins, obtaining results that show a dramatic difference between both products.[1]

Table 1 summarizes some typical critical pressure values (S4 and the corresponding values converted to the FS test) for unimodal and bimodal types of PE, obtained from tests carried out on pipes with a nominal diameter of 12 inches (Ø305mm) and SDR=11.

Table 1. RCP analysis for PE types

POLYETHYLENE	P Crítical (S4) a 0°C (bar)	P Crítical (FS) a 0°C (bar)	T Crítical (Tc °C)
Unimodal MDPE	1	6.2	<15
Bimodal MDPE	10	38.6	<-2
Unimodal HDPE	2	9.8	<9
Bimodal HDPE (PE100+)	12	45.8	<17

Unimodal polyethylene resins present a molecular weight distribution (MPD) as indicated in Figure 6, where a normal distribution with a single peak can be seen.

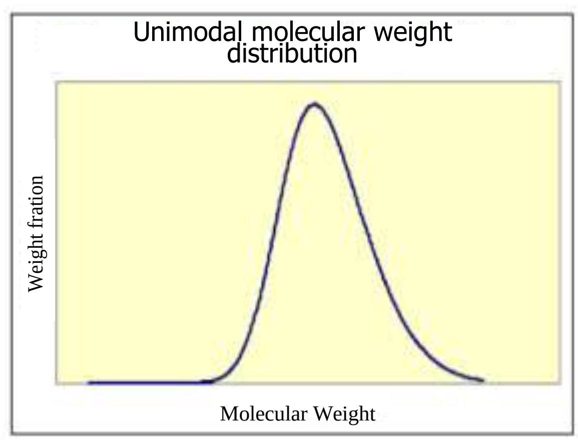

Figure 6. Unimodal PE resin

Bimodal PE resins present a molecular weight distribution with two peaks, coming from the superposition of two individual molecular weight distributions, with the comonomer distribution towards the high molecular weight fractions. This very particular molecular weight distribution (see Figure 7) allows superior mechanical properties to be achieved without sacrificing the processability of the resin, as is the case with Venelene 7700M.

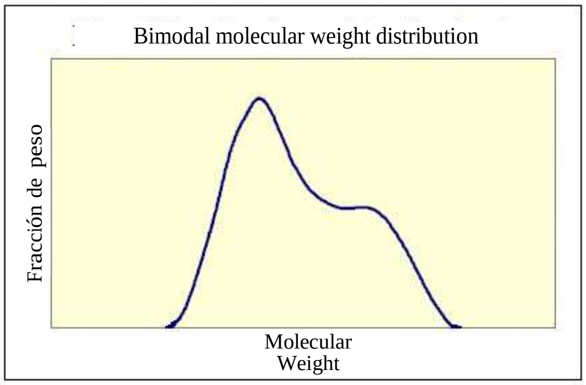

Figure 7. Bimodal PE resin.

Critical Temperature: RCP events can occur in PE pipes made with unimodal resins, type PE100, at temperatures below 15°C (60°F). As can be seen in Figure 8, there are well-identified zones for this type of material, where the safe zone ("safe", green color) is above 15°C for pipes larger than Ø5 inches (127mm) in diameter[6].

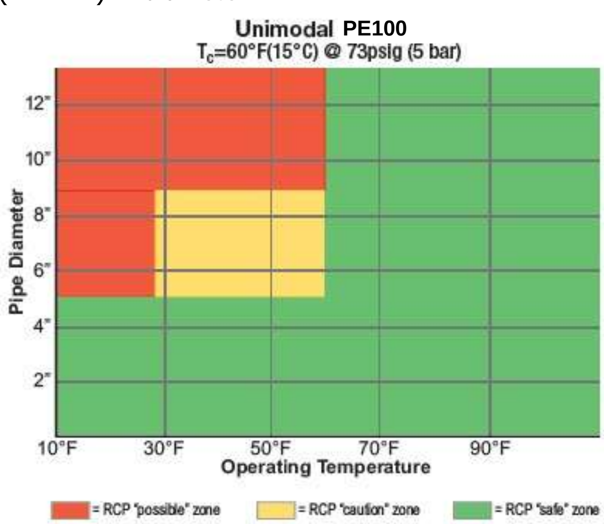

Figure 8. Critical temperature for PE pipes Unimodal

In the case of pipes made with bimodal resins, the critical temperature is around -2°C (28°F), with the elimination of areas with possible RCP events ("possible" - red) for the range of temperatures considered. (see Figure 9).

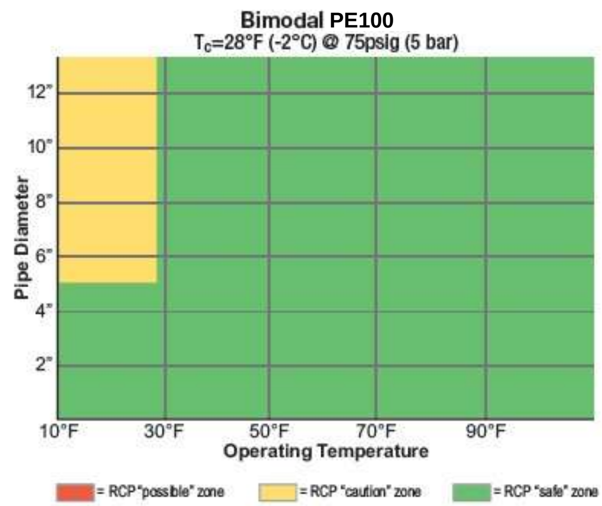

Figure 9. Critical temperature for PE pipes bimodal.

Critical Pressure: In a piping system made of PE 100 unimodal, an RCP event can occur when the operating pressure exceeds 90 psi (6 bar) at a temperature of 0°C (32°F).

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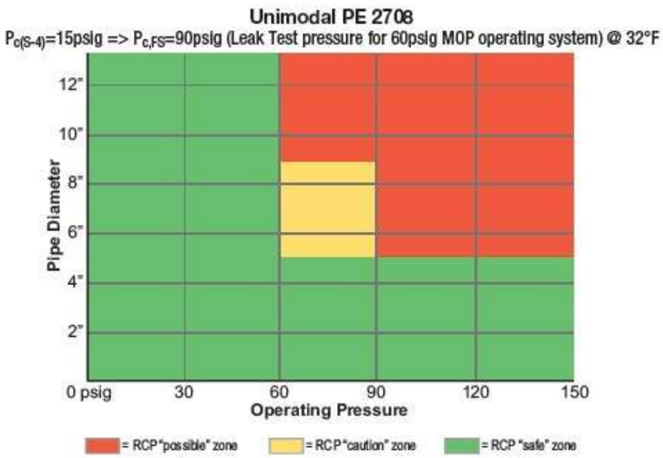


Figure 10. Critical pressure for unimodal PE pipes.

Additionally, there is a zone between 60 and 90 psi (4 to 6 bar) called the "caution zone" ("caution – yellow in Figure 10) that must be considered as a design safety factor for RCP of 1.5:1, when estimating the SDR to manufacture.

Figure 11 indicates that there are no critical zones for tubes made with bimodal resins, since they have critical pressure values of up to 560 psi (38 bar), at operating temperatures of 0°C (32°F).

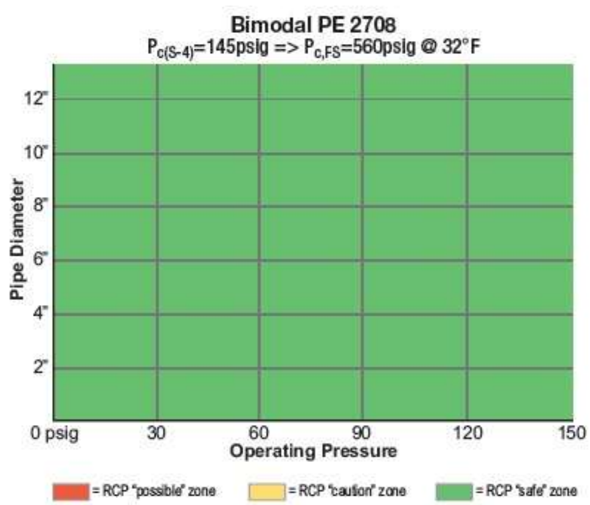
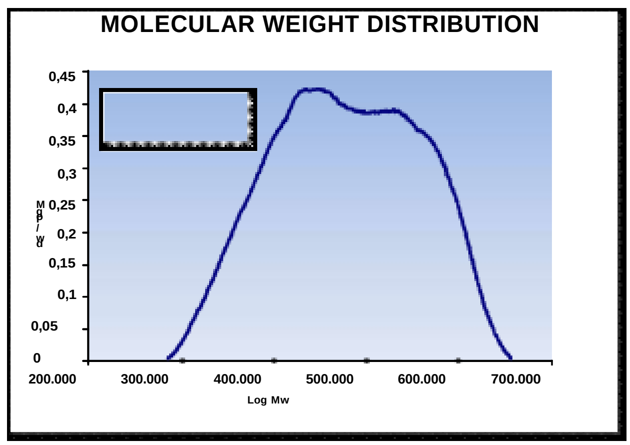


Figure 11. Critical pressure for bimodal PE pipes.

4. Venelene® 7700M resin

Polinter offers, among its products, the PE100 Venelene® 7700M type resin, specially designed for the extrusion of pipes, whose characterization allows it to be identified as a bimodal resin. Its higher molecular weight and density promote, in tubes made with Venelene® 7700M, an increase in resistance to creep (slow growth of cracks), application of higher working pressures and safety against potential RCP events.

Select an SDR of 29 as the minimum value to handle the occurrence of RCP, using typical values of 21, 17, and 13.5.



5. VARIABLES THAT AFFECT RCP IN HDPE PIPE

Plastic material of the tube: the resistance to Impact is a measure of the toughness of a material and allows detecting how brittle or ductile it is a resin and its ability to absorb impact without breaking.

In general, the more fragile is a material, more susceptible to RCP. The HDPE for pipes is a ductile material with high impact resistance.

Dimensions (diameter and SDR): the events of RCP tend to increase as you increase the diameter of the pipe. These do not occur in Ø4 inch pipes (Ø100mm). For transport water or gas, you must select the diameter with special care to minimize the RCP events. For HDPE pipes, you must select and SDR as the minimum value for handle the appearance of RCP, using values typical of 21, 17 and 13,5.

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Internal pressure: supplies the energy to propagate cracks in the pipe. The greater the internal pressure, the greater the probability that a CPR event will occur and it must be designed considering this premise. For HDPE pipes tested at RCP, the event occurs when the pressure of 600 psi (41 bars) is exceeded for bimodal resins (PE100), an aspect that practically cancels the appearance of the event for the usual working temperatures.

Ground temperature: For all plastic materials, an RCP event is more likely to occur at temperatures below 0°C, where the material becomes brittle. At lower temperature, the greater the occurrence of RCP.

Air trapped in the pipe: Due to the ductility of HDPE pipe, RCP failure does not occur when it is completely filled with water. The presence of small amounts of air aids crack propagation, generating a sinusoidal pattern along the length of the pipe.

6 ¿ How to design HDPE pipes to avoid RCP?

- Select a PE 100 with high resistance to RCP. Prefer PE with bimodal DPM.
- Choose at least one SDR 29, preferably SDR 21, SDR 17 or SDR 13.5.
- Promote best manufacturing practices during pipe manufacturing.

7 References Bibliography

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