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WEBINAR VIII

21-10-2021

Thermoplastic Pipe Systems:

Important aspects to understand and keep in mind during design and specification

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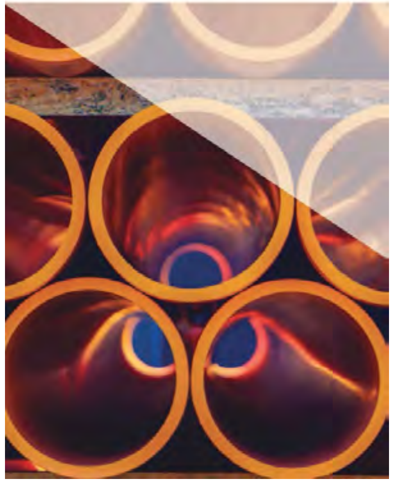

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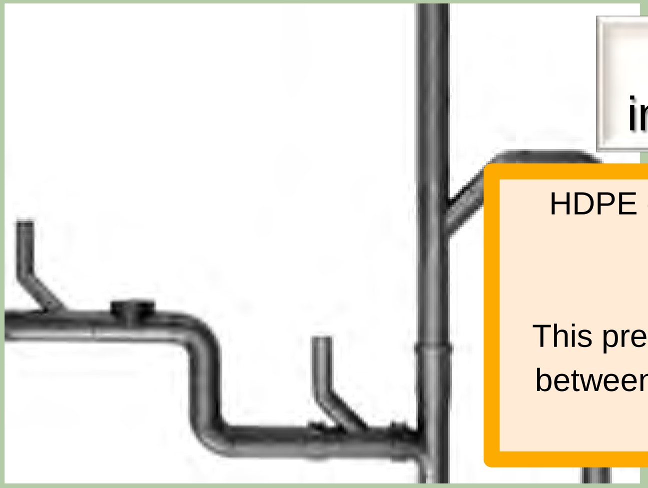

HDPE Pipe Systems –Essential information for Designers and Contractors

HDPE continues to be the material of choice for potable water distribution systems in some countries.

This presentation draws attention to some of the more important differences between PVC and HDPE piping systems that cause problems for designers and contractors.

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International Webinar

21 October 2021

HDPE Pipe Systems: Essential Information for Designers and Contractors

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OVERVIEW
of this presentation

PVC and HDPE: Similarities and Differences
Joints in PVC and HDPE Pipe Systems
Poisson's Effect
Thermal Effects
Total Stress
Modulus of Elasticity
Visco-Elastic material
Pressure testing
Joining HDPE Pipes with Different Wall Thicknesses

PVC and HDPE Pipes:
The main similarities

	PVC	HDPE	Benefit
elastic	√	√	reduces water hammer
malleable	√	√	does not shatter on impact
mouldable	√	√	easy to shape
recyclable	√	√	“green”
corrosion resistant	√	√	no (CP) required, long life
lightweight	√	√	easy to handle

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PVC and HDPE pipes:
Some Important differences

	PVC	HDPE
Can joints resist tension?	NO	YES but only if the joints are tension resisting
Can joints resist internal vacuum?	NO	PARTIAL - If properly bedded
Are the pipes continuous?	NO	YES - normally welded or flanged

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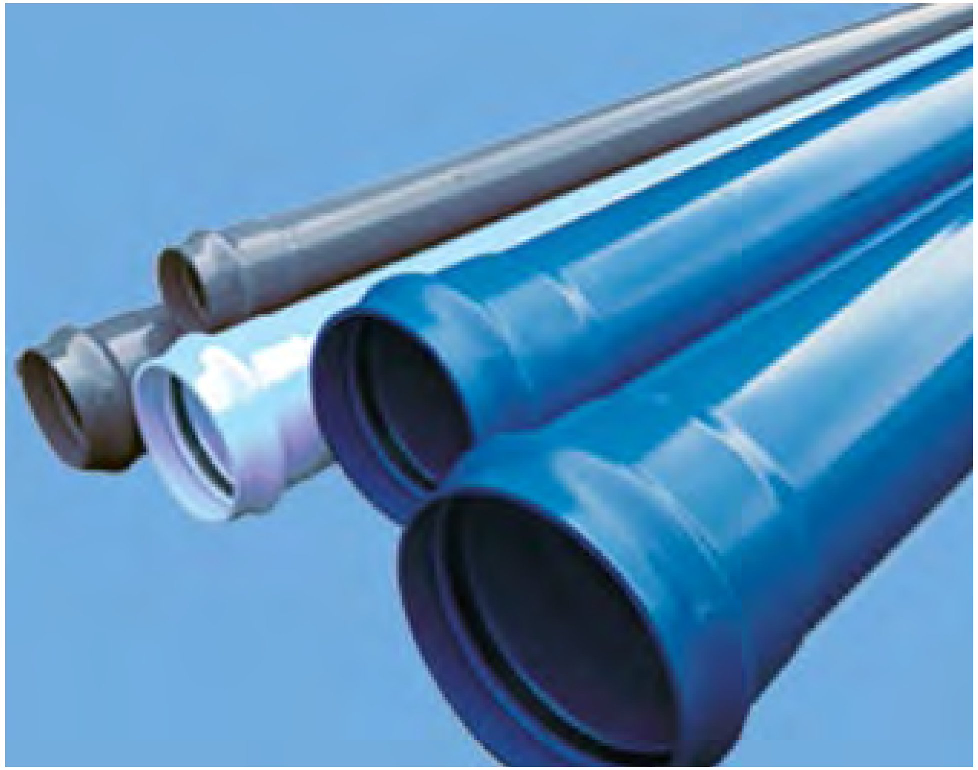
JOINTS IN
PVC
PIPE SYSTEMS

PVC pipe joints



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Typical PVC pipes in trenches

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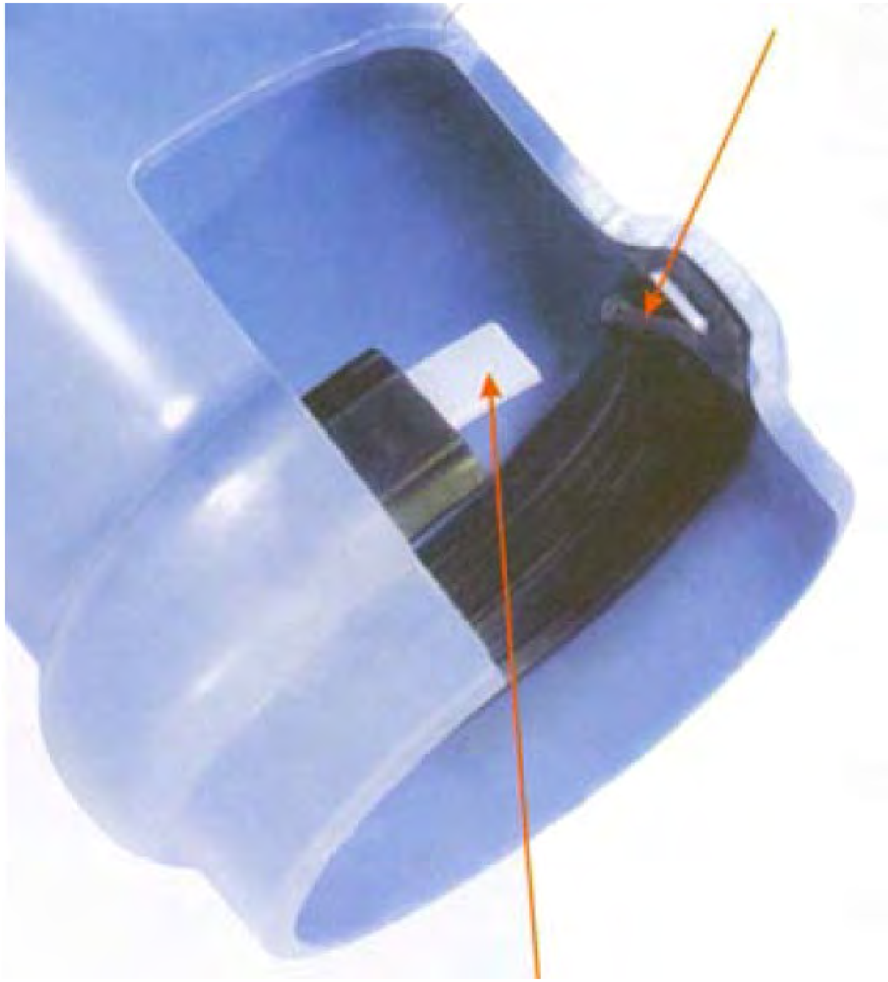
Typical spigot & socket joint in PVC pipes



- Joints have ZERO effective capacity to resist longitudinal tension

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Typical flexible coupling

- Joints have ZERO effective capacity to resist longitudinal tension

JOINTS IN
HDPE
PIPE SYSTEMS

Joints in HDPE Pipe Systems

Heat Fusion Connections

- Butt fusion
- Electro-fusion couplings
- Extrusion welding (low strength)

Mechanical Connections

- Flanged connections

  = butt fused stub flange and bolted steel backing ring
- Tension resisting couplings

Fittings for HDPE systems

Moulded Fittings

- Do not need to be de-rated

Fabricated fittings

- Must be de-rated

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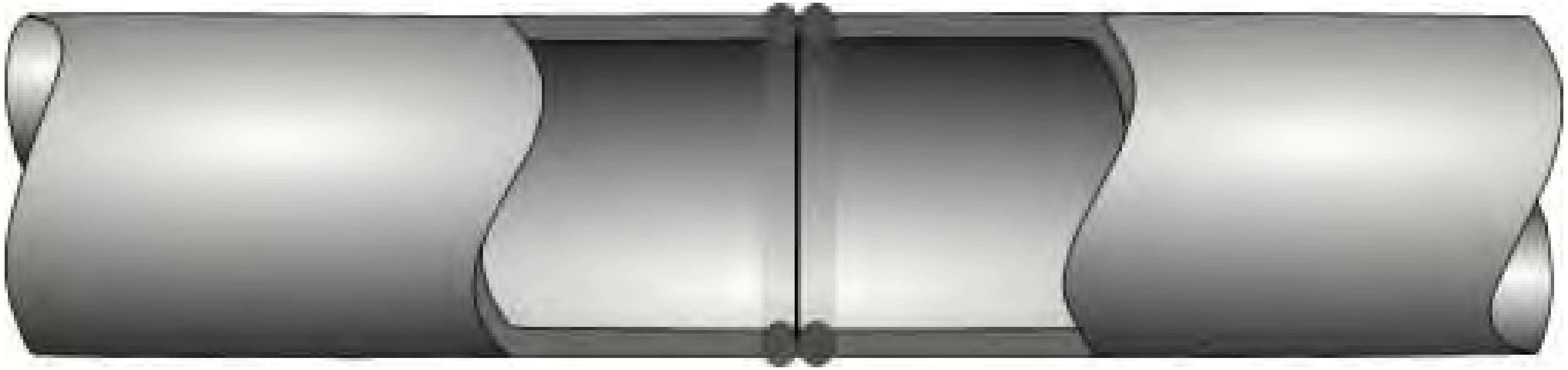
Heat Fusion Connections: Butt Fusion



Standard Butt Fusion Joint

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Heat Fusion Connections: Butt Fusion

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Heat Fusion Connections: Butt Fusion

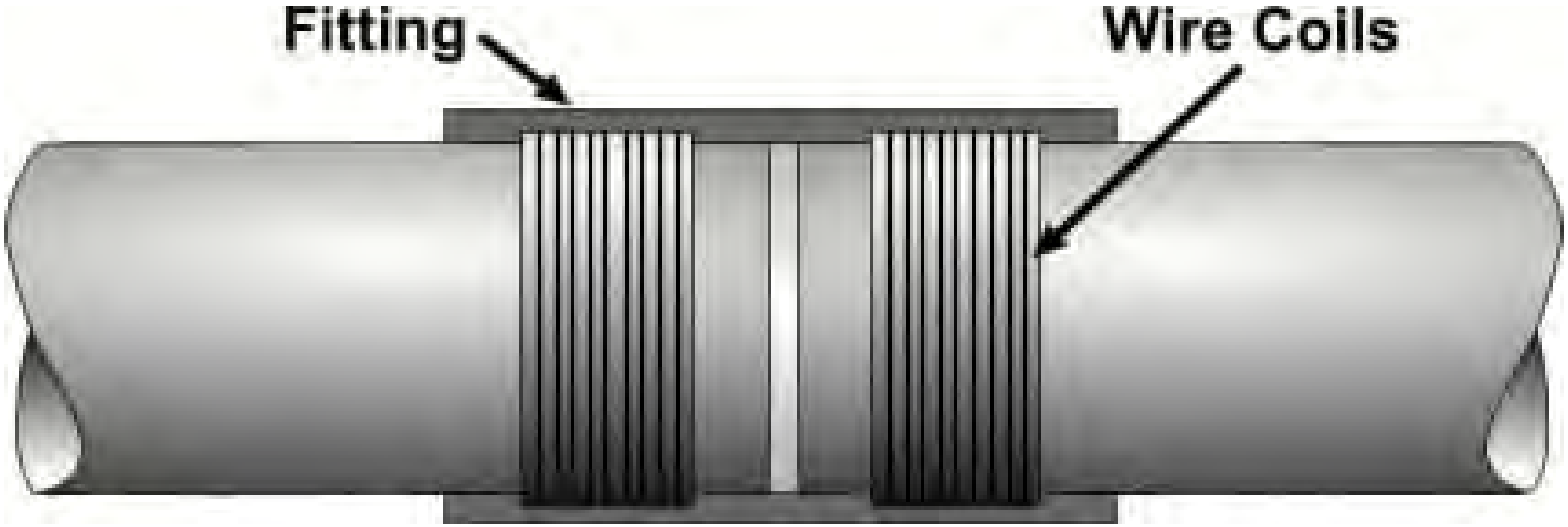
Critical details:

- Square, clean faced pipes
- Temperature
- Pressure
- Time for fusing
- Time for cooling

Heat Fusion Connections: Butt Fusion

- Reliable, calibrated
- Clean cut / surface preparation (“facing”)
- Computer controlled (bar coded inputs)
- Machine locks pipe for correct cooling period

Heat Fusion Connections: Electrofusion



Typical Electrofusion Joint

Heat Fusion Connections: Electrofusion

Electro fusion Couplings

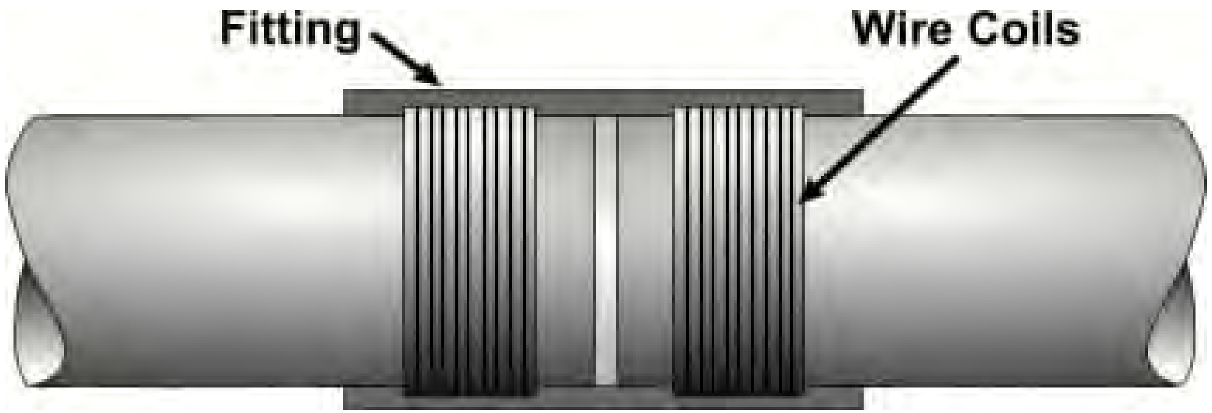
Typical Electrofusion Control Box and Leads with Clamps and Fittings

- Reliable, calibrated
- Portable
- Surface preparation can be difficult to achieve in the field
- Computer controlled (bar coded inputs)

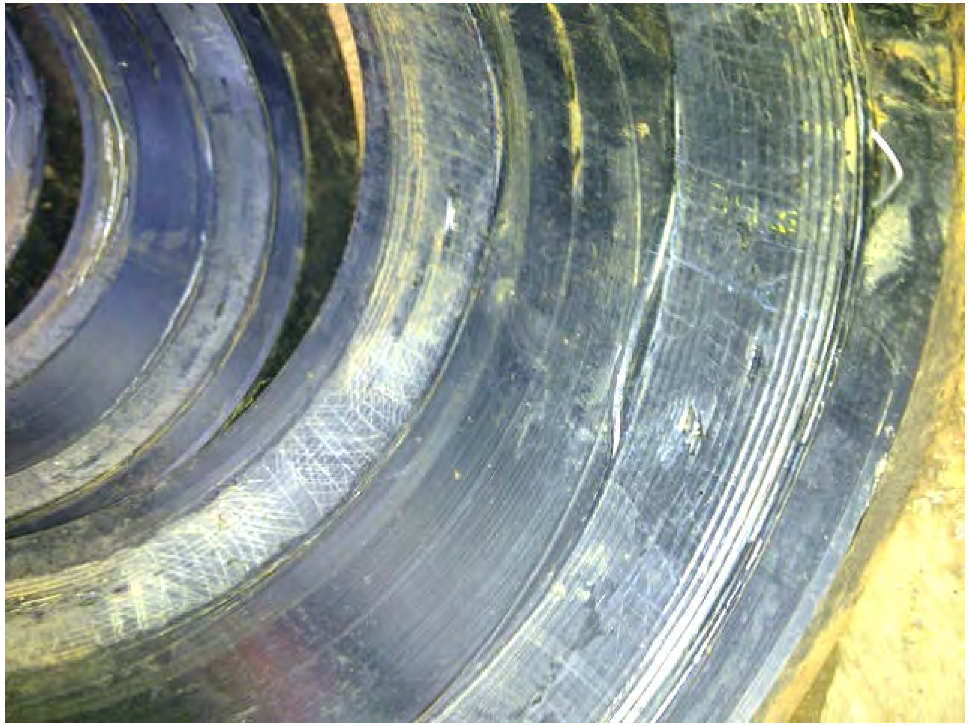
Heat Fusion Connections: Electrofusion

Critical details:

- Ends of pipe reamed to remove oxidised material
- Absolute cleanliness is essential
- Conditions must be dry and dust free
- Snug fit required between pipe and coupling
- Time for fusing, time for cooling must be controlled



Heat Fusion Connections: Electrofusion



Example: Failed electrofusion coupling

- poor surface preparation (not reamed, dirty)
- incomplete formation of melt pool
- partial fusion
- pipe moved before cooling

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Heat Fusion Connections: Extrusion Welding

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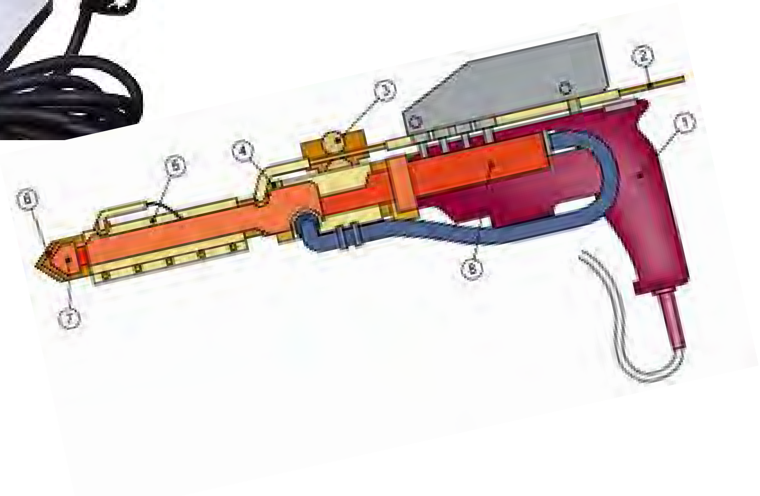
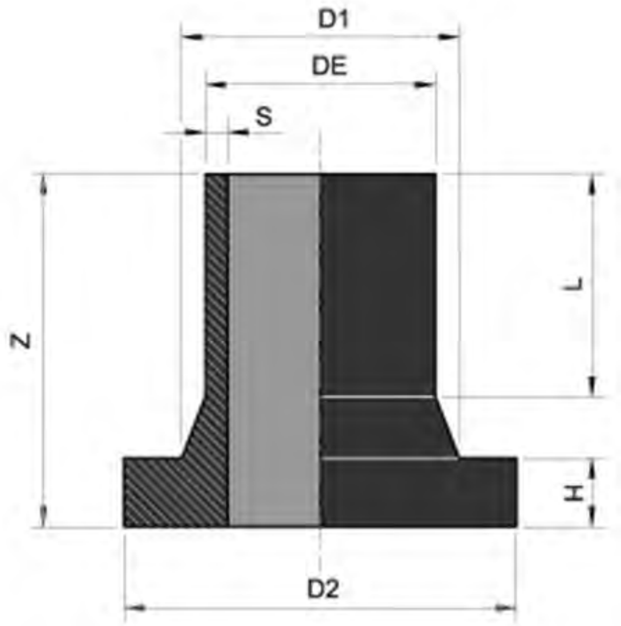
Heat Fusion Connections: Extrusion Welding



Mechanical Connections: Stub Flanges



Typical pair of moulded HDPE stub flanges (for butt welding) and Ductile Iron Flanges (bolts and nuts not shown)

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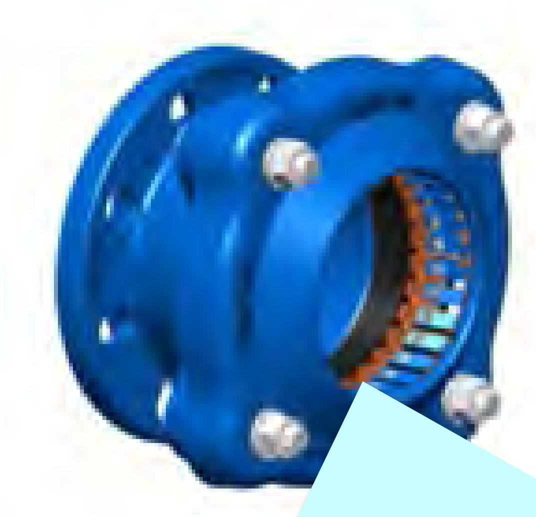
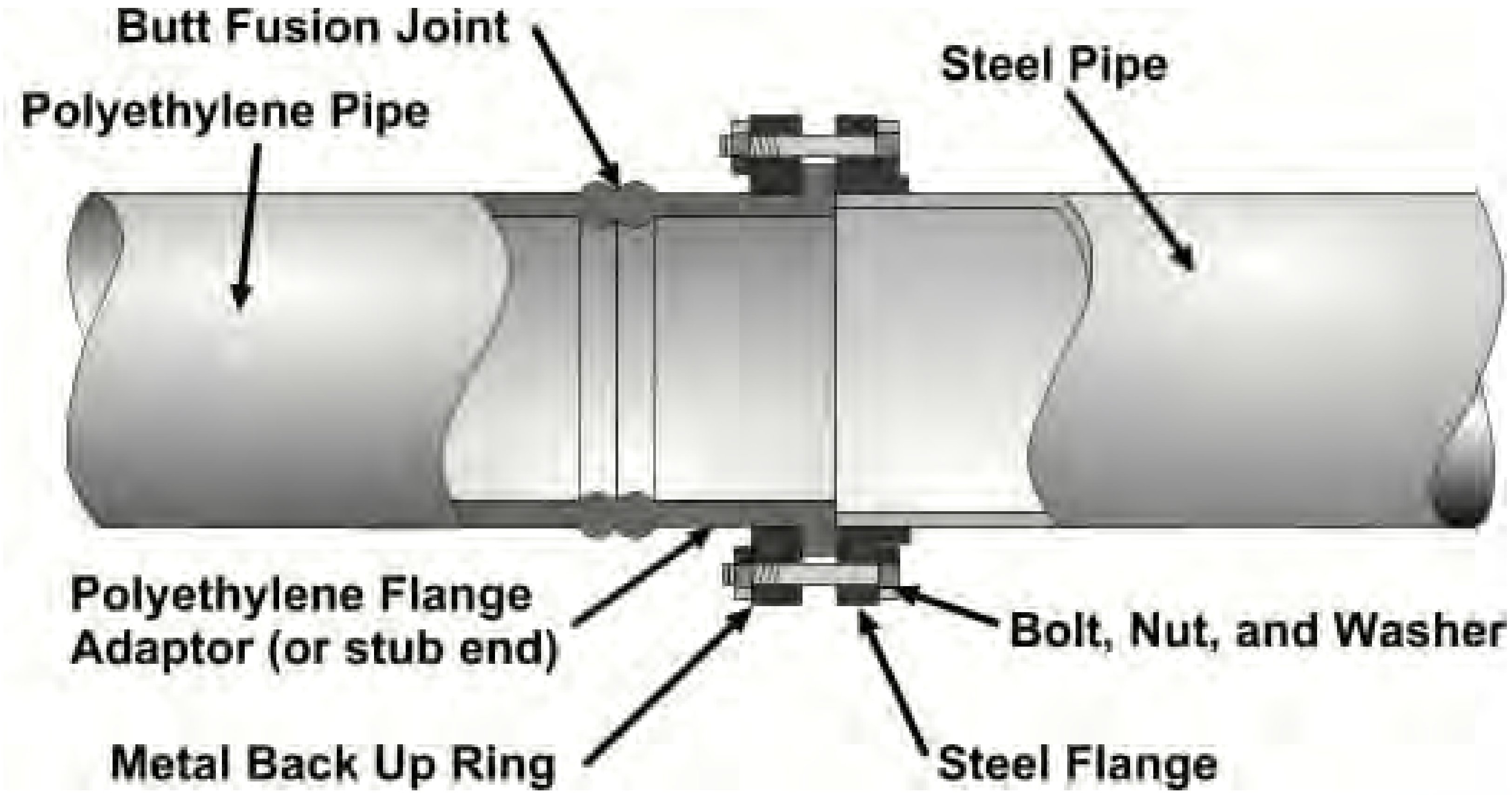
Mechanical Connections:
Tension Resisting couplings

Can be used if electrofusion is not feasible, eg water in pipe (leaking valves), emergency repairs etc)



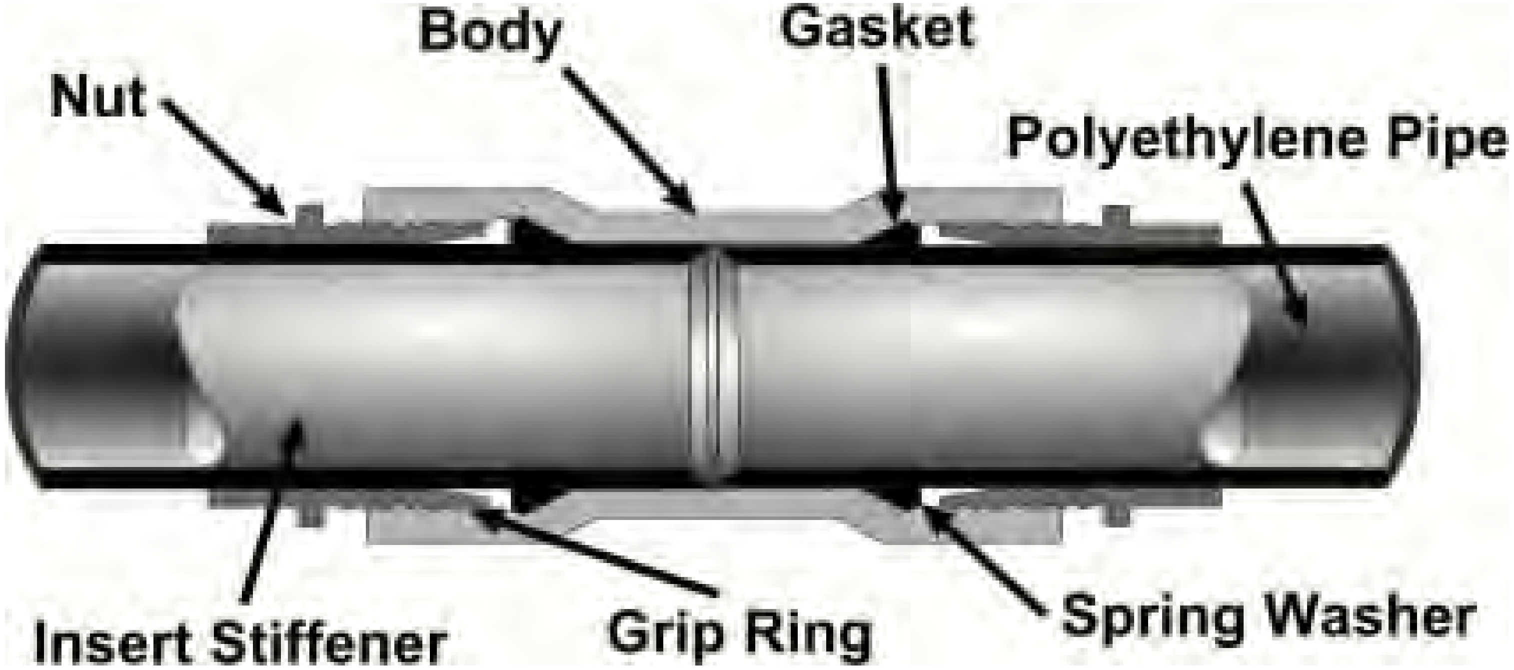
Note:
1. “Grip Rings” have sharp-edges that “bite” into the PE material to prevent the pipe from pulling out (see Poisson, Thermal effects)
2. Internal stiffeners are required to avoid the pipe deforming and losing grip (see visco-elastic properties)

Mechanical Connections



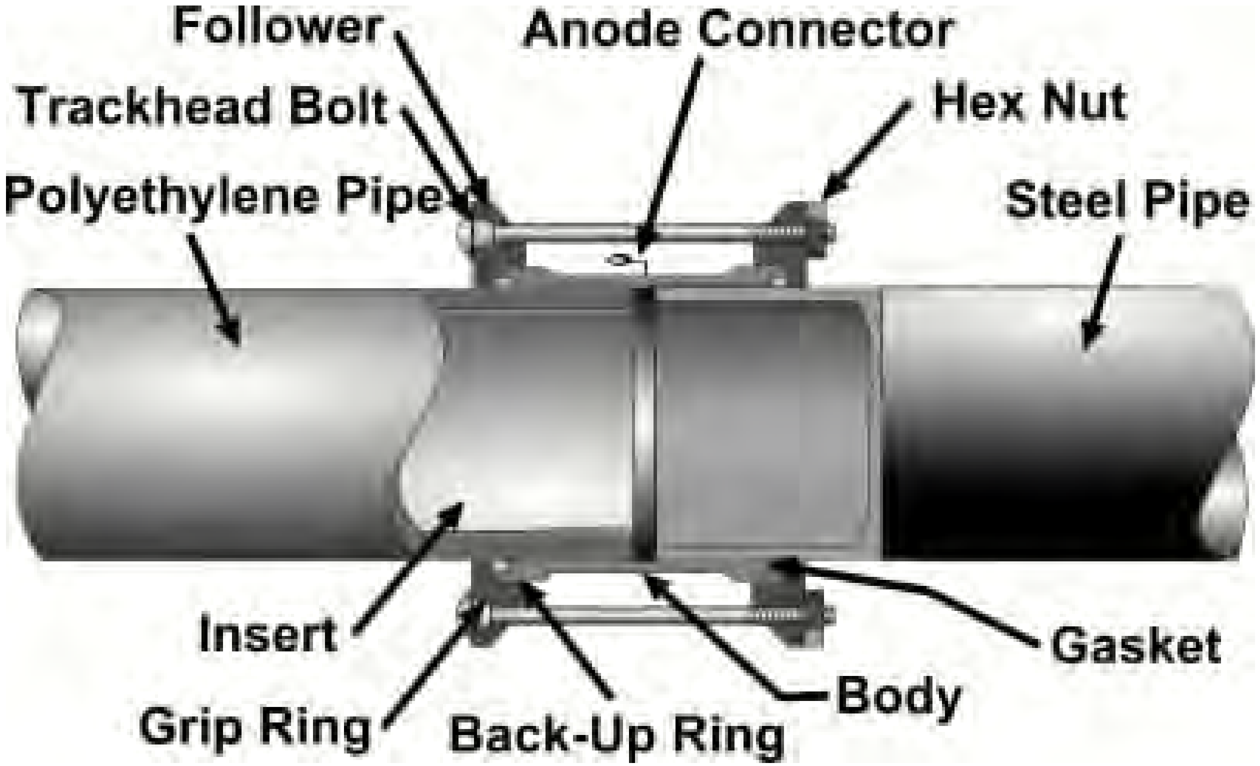
Typical Application of Polyethylene Flange Adapter or Stub End

Mechanical Connections



Typical Compression Nut Type Mechanical Plastic Coupling for Joining Polyethylene to Polyethylene

Mechanical Connections



Bolt Type Mechanical Coupling for Joining Steel Pipe to Polyethylene or for Joining Two Polyethylene Pipes

Mechanical Connections

LAP-JOINT STYLE FLANGE ASSEMBLIES

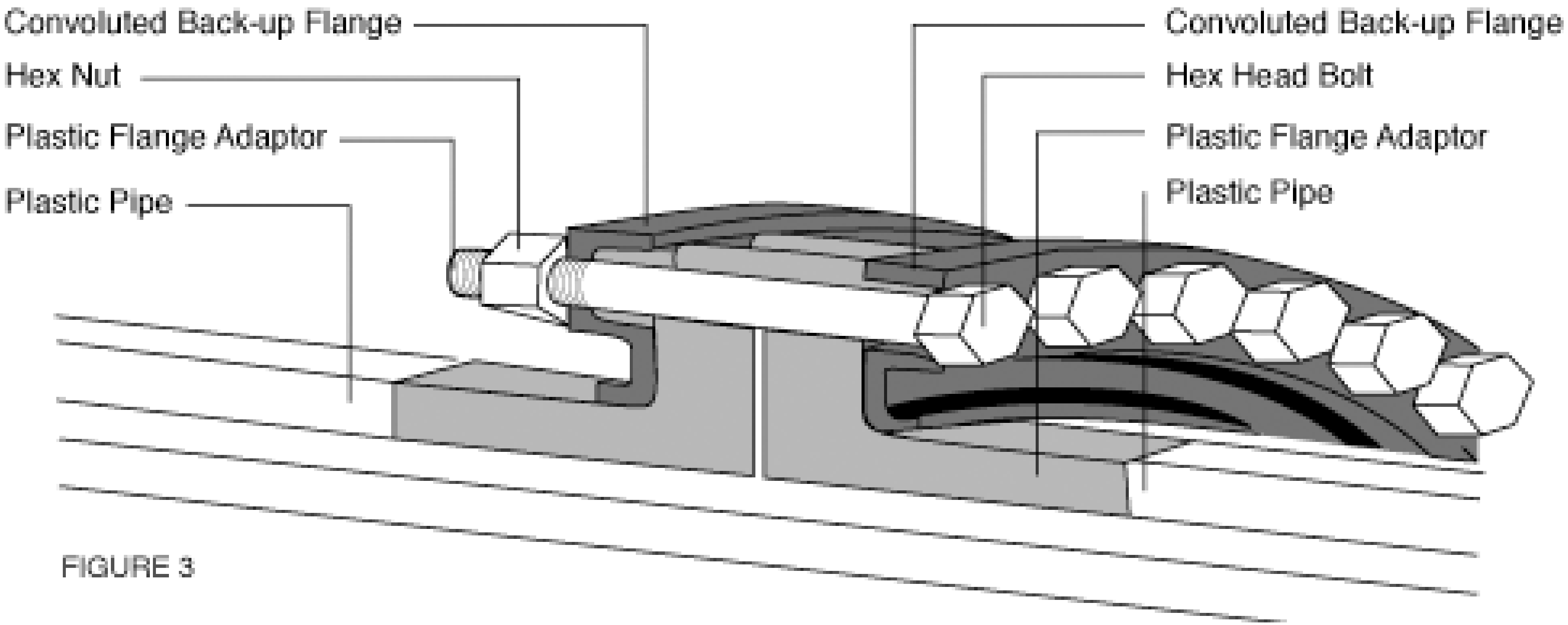


FIGURE 3

Cast Stainless Steel, Lap-Joint Flange (LJF)

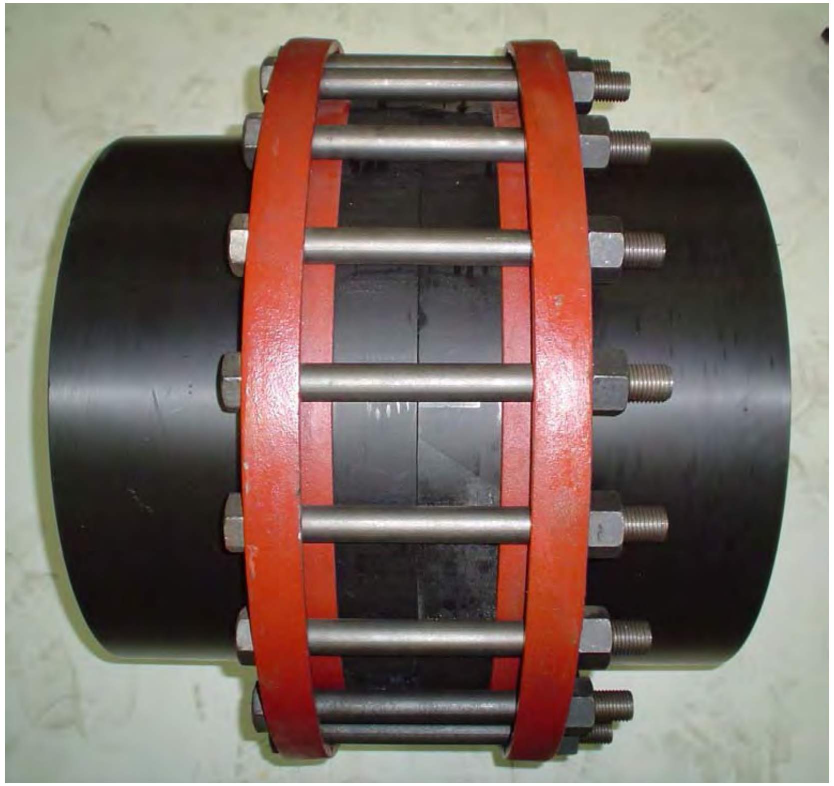
Lap-Joint Flanges are
> elastic, resilient, flexible “plate-spring”
> engineered to work with HDPE stub flanges

When the bolts are torqued, the LJF flexes and applies a uniform compression to the stub flange.

Bolts are torqued so that average stub flange thickness compresses 2% to 5%.
At this low level of strain:
1) The compressed HDPE stub flange face is still elastic and can recover
2) When it is subjected to thermal pipe contraction, or vibration, or bolt stretch, the “plate-spring” flange recovers elastically so as to maintain the required minimum level of, pre-loaded, interfacial sealing pressure on the HDPE faces.

Mechanical Connections

LAP-JOINT STYLE FLANGE ASSEMBLIES



DN 600 (24”) Polyethylene Stub Flanges with Metal Lap-Joint Flanges and Bolt Set

Cast Stainless Steel, Lap-Joint Flange, 6-inch IPS

Important Design Considerations for HDPE Pipes

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Hoop Stress

Barlow's Formula:

$$\delta = \frac{-\,p\,(d_e - e)}{2\,e}$$

"Primary Stress"

where δ = hoop stress in the pipe wall (MPa)

p = internal pressure (MPa)

d_e = mean external diameter (mm)

e = min. wall thickness (mm)

Poisson’s Effect

and

1. Longitudinal Strain

2. Longitudinal Stress

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Poisson’s Effect
And
Poisson’s Ratio

When a material is stretched it usually contracts in the directions transverse to the direction of stretching (eg when a rubber band is stretched it becomes noticeably thinner).

This phenomenon is called the **Poisson effect**.

The ratio between these two quantities is known as **Poisson's ratio** (η).

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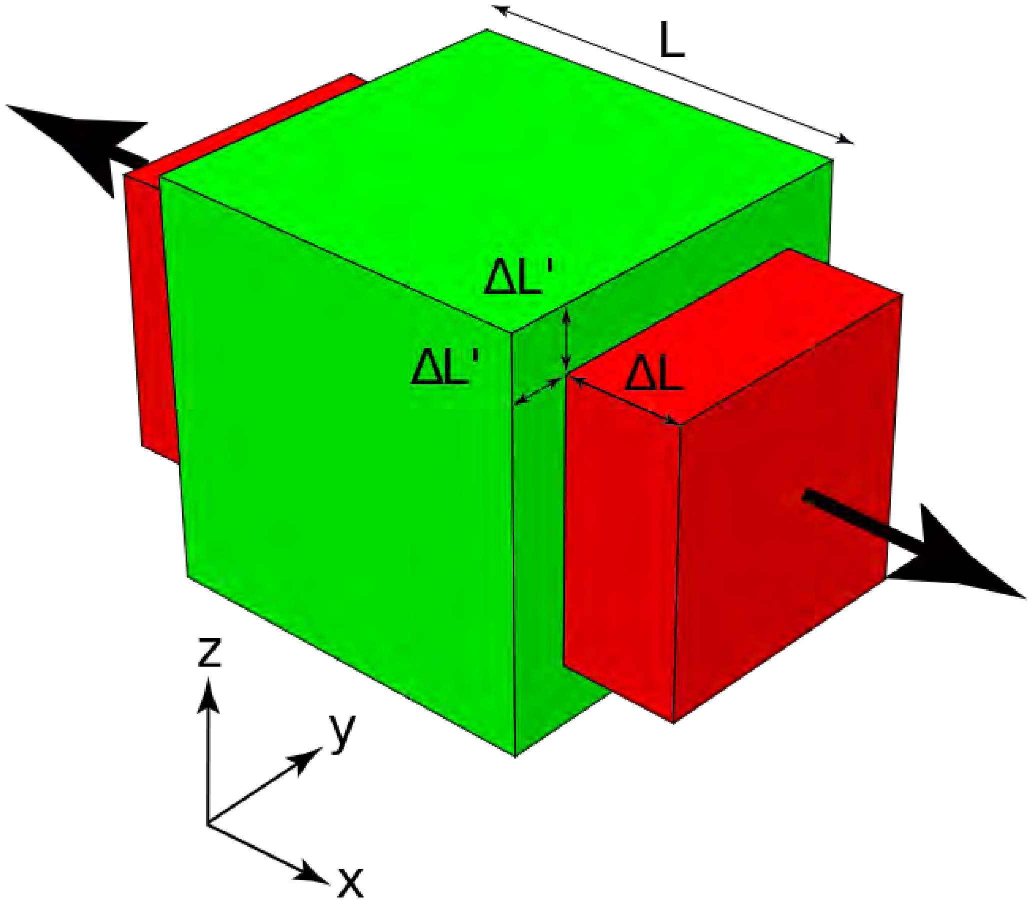
Poisson’s Effect



Poisson Effect:
Longitudinal Strain In Pipes

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Poisson Effect :
Longitudinal Strain In Pipes

When the liquid inside a pipe is pressurized it exerts a uniform force on the inside of the pipe, resulting in a radial stress within the pipe material.

Due to Poisson's effect, this radial stress will cause the pipe to slightly increase in diameter and decrease in length as indicated by **ΔL** in the diagram below.

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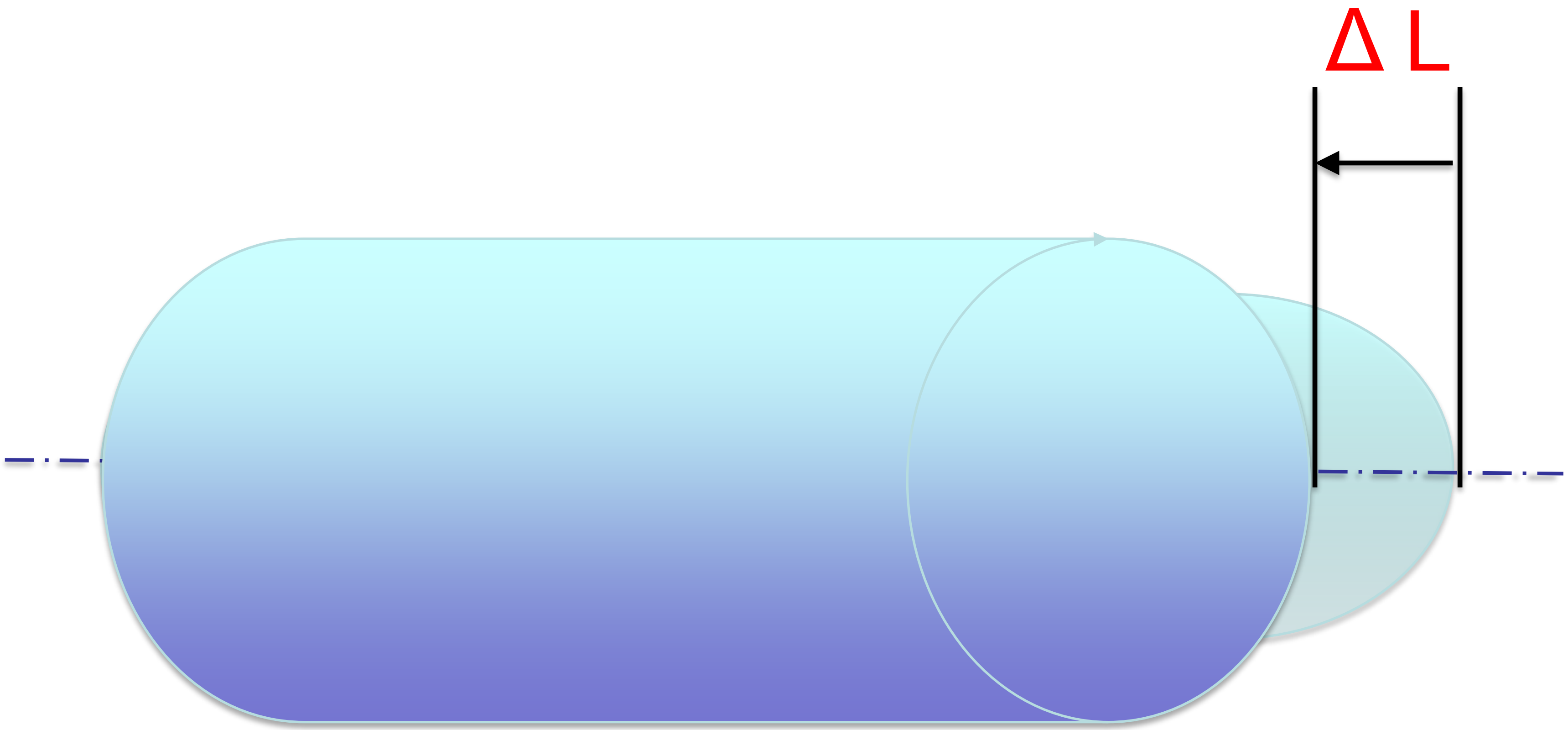
Δ L

Poisson Effect : Longitudinal Strain In Pipes

$$\Delta L = \frac{P\,d\,L}{4\,t\,E} \cdot (1 - 2\eta)$$

where Δ L = change in pipe length (mm)

P = internal pressure (kPa)

d = pipe diameter (mm)

L = original pipe length (m)

t = pipe wall thickness (mm)

E = Elastic Modulus (MPa)

η = Poisson's Ratio (0,38 for PE 100)

Poisson Effect : Longitudinal Strain In Pipes

EXAMPLE

Lo	=	100	m
P	=	16	bar
OD	=	251	mm
t (ave)	=	35,75	mm
E	=	758	MPa
L1	**=**	**89**	**mm**

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Poisson Effect :
Longitudinal Strain In Pipes
- WHY IS THIS IMPORTANT?

In PVC pipes that are joined with “spigot and socket” type joints the decrease in length in each individual pipe is negligible and it is not cumulative from pipe to pipe, therefore the Poisson effect is not critical in most PVC pipe systems.

However, in continuously jointed HDPE pipes the total decrease in length and the associated tensile force becomes significant. At unrestrained joints the pipes can fail by pulling out of the couplings. At restrained joints the pipes or the couplings may be prone to various forms of failure if the stresses are very high hence the designs need to be analysed, detailed and specified carefully.

Poisson Effect :
Longitudinal Strain In Pipes
- WHY IS THIS IMPORTANT?

The point is:
Don't use unrestrained, flexible
("VJ" type) joints in HDPE pipe systems
....

EVER

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Poisson Effect :
Longitudinal Stress In Pipes

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Poisson Effect :
Longitudinal Stress In Pipes

If a pipe is pressurized and restrained at both ends to prevent it from decreasing in length, the force required at each restraint can be calculated according to the formula on the following slide.

Conversely, this is also the force required to “stretch” the pressurized pipe back to its original length.

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Poisson Effect :
Strain and Longitudinal Stress In Pipes

$$F = \frac{E \cdot A_o \cdot \Delta L}{1000 \cdot L_o}$$

Where

- F = force to resist change in length (kN)
- E = elastic modulus (MPa)
- Ao = cross sectional area of pipe (mm^2)
- ΔL = change in pipe length (m)
- Lo = original length of pipe (m)

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Poisson Effect :
Strain and Longitudinal Stress In Pipes

Lo	= 100	m
ΔL	= 89	mm
P	= 16	bar
OD	= 251	mm
t (ave)	= 35,75	mm
E	= 758	MPa

EXAMPLE

F = 16,3 kN

(1,66 tonnes)

Thermal Effects

and

1. Longitudinal Strain

2. Longitudinal Stress

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Thermal Effect :
Longitudinal Strain In Pipes

The expansion of pipes due to a temperature change depends on the start and final temperature (**Δ T**) of the pipe and the expansion coefficient of the piping material at the actual temperature.

The general expansion formula for unrestrained pipe can be expressed as shown on the following slide.

Thermal Effect :
Longitudinal Strain In Pipes

$$\Delta L = Lo \cdot \alpha \cdot \Delta T$$

where ΔL = change in pipe length (m)

Lo = original, unrestrained pipe length (m)

α = thermal expansion coefficient

(**120** to **140** x 10^{-6} m/m/ºC for PE 100)

ΔT = change in temperature (ºC)

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Thermal Effect : Longitudinal Strain In Pipes

EXAMPLE

Lo	=	100	m
α	=	$140x10^{-6}$	m/m/ºC
Δ T	=	20	ºC

Δ L = 280 mm

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Thermal Effect :
Strain and Longitudinal Stress In Pipes

EXAMPLE

Lo	=	100	m
ΔL	=	280	mm
P	=	16	bar
OD	=	251	mm
t (ave)	=	35,75	mm
E	=	758	MPa

F = 51,3 kN

(5,23 tonnes)

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Total Stress:

1. Poisson’s Effect

+

2. Thermal Effect

+

3. Hoop Stress

+

4. Bending

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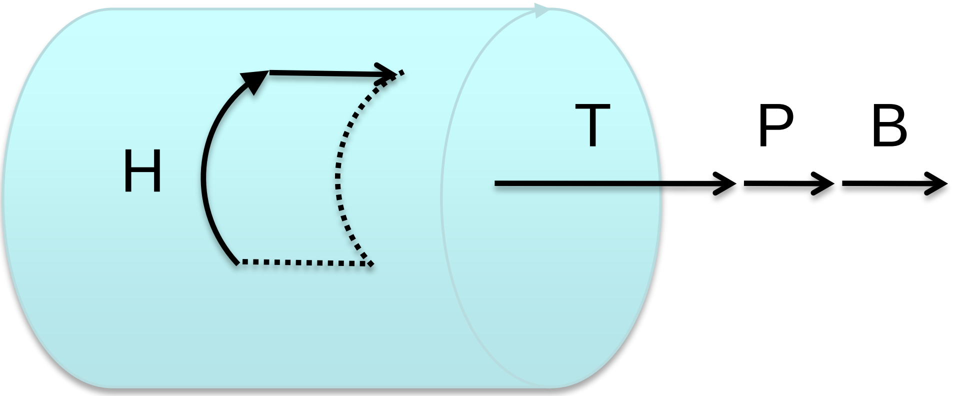
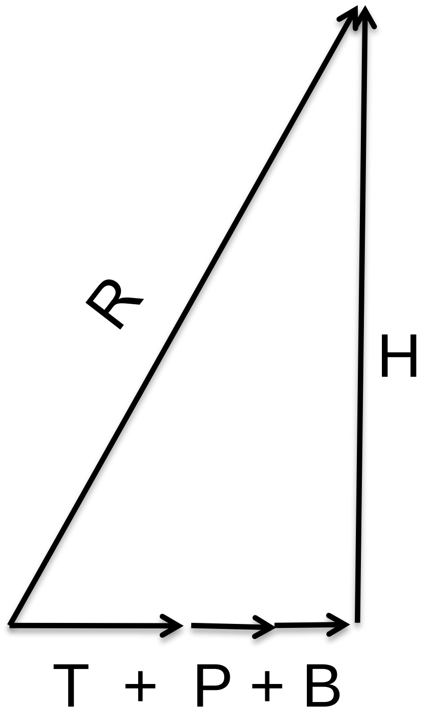
Total Stress
= Hoop + Thermal + Poisson's + Bending

$$R = \sqrt{(H)^2 + (T + P + B)^2}$$





R < MRS
(Minimum Required Strength)
= 10 N/mm^2 for PE 100

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MODULUS
OF
ELASTICITY

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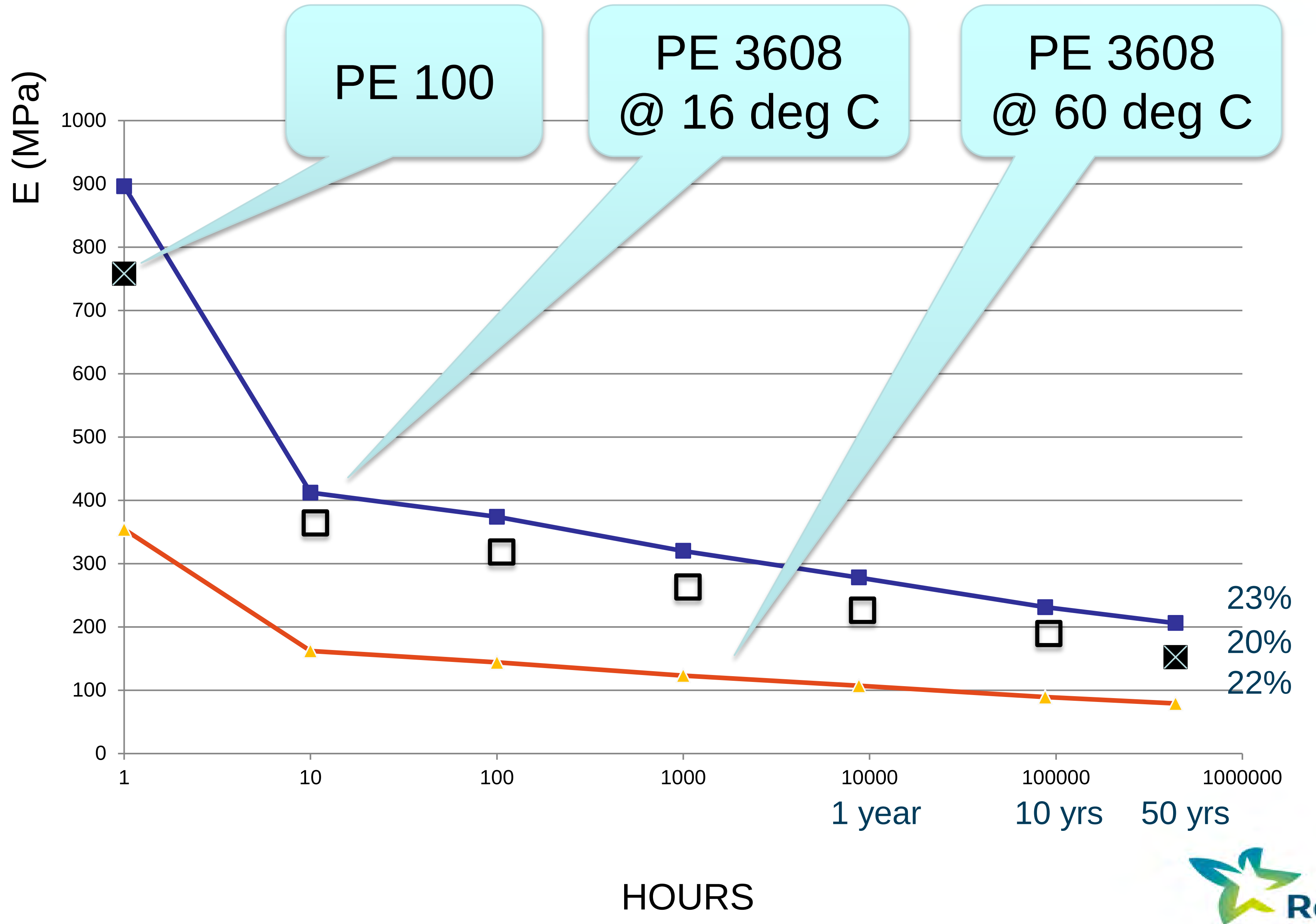
Modulus needs to be adjusted to suit Time, Temperature, and medium being conveyed

Modulus of Elasticity (MPa) *			
	PE 100	PE 3608 @ 16 deg C	PE 3608 @ 60 deg C
Short Term	758	896	354
10 h		412	162
100 h		374	144
1000 h		320	123
1 y		278	107
10 y		231	89
50 y	152	206	79

*Obtain suitable Apparent E Modulus from Compound producers Type Test report ISO 12162, ISO 9080

PE3608 – Cell Classification ASTM D3350



PE 100
PE 3608
@ 16 deg C
PE 3608
@ 60 deg C
E (MPa)
1000
900
800
700
600
500
400
300
200
100
0
1
10
100
1000
10000
100000
1000000
1 year
10 yrs
50 yrs
23%
20%
22%
HOURS

Visco-Elastic Relaxation

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Residual Bolt Torque (RBT) & Mandatory 4 to 24 Hour Re-Torquing

Initial bolt torque slowly declines to about 35% of initial torque.
This is due to visco-elastic creep-relaxation of the HDPE material and it is normal.

The initial bolt torque only seats the HDPE flange-adapter face
(ie. to deform a “no-leak” path in the HDPE).

The residual bolt torque seals the flange face
(ie. to provide long term sealing stress).

A minimum residual bolt torque (RBT) is required to
- provide elastic HDPE compression for sealing the pipe joint
- reserve for surge pressure
- bolt-tension scatter
- other variables

Are gaskets required between the faces of HDPE flange adapters?

Generally gaskets are not recommended or needed when connecting two mating HDPE flanges at 550 kPa / 55 bar (80 psi) or less.

However, special tightening is required and that may include re-tightening of the bolts in 4-hours to 24-hours after the initial torque. PPI publishes a technical note, TN 38 that deals with this subject in considerable detail and with other options for flanged connections made between HDPE and other pipe materials. It is strongly recommended that the design engineer/contractor refer to this document when faced with issues of design or assembly of any flanged connection involving HDPE pipe.

Testing of HDPE pipes

Pressure testing to SABS 1200 L:

- Only works for rigid or semi-rigid pipes (PVC included)

- is not appropriate for the visco-elastic nature of HDPE material

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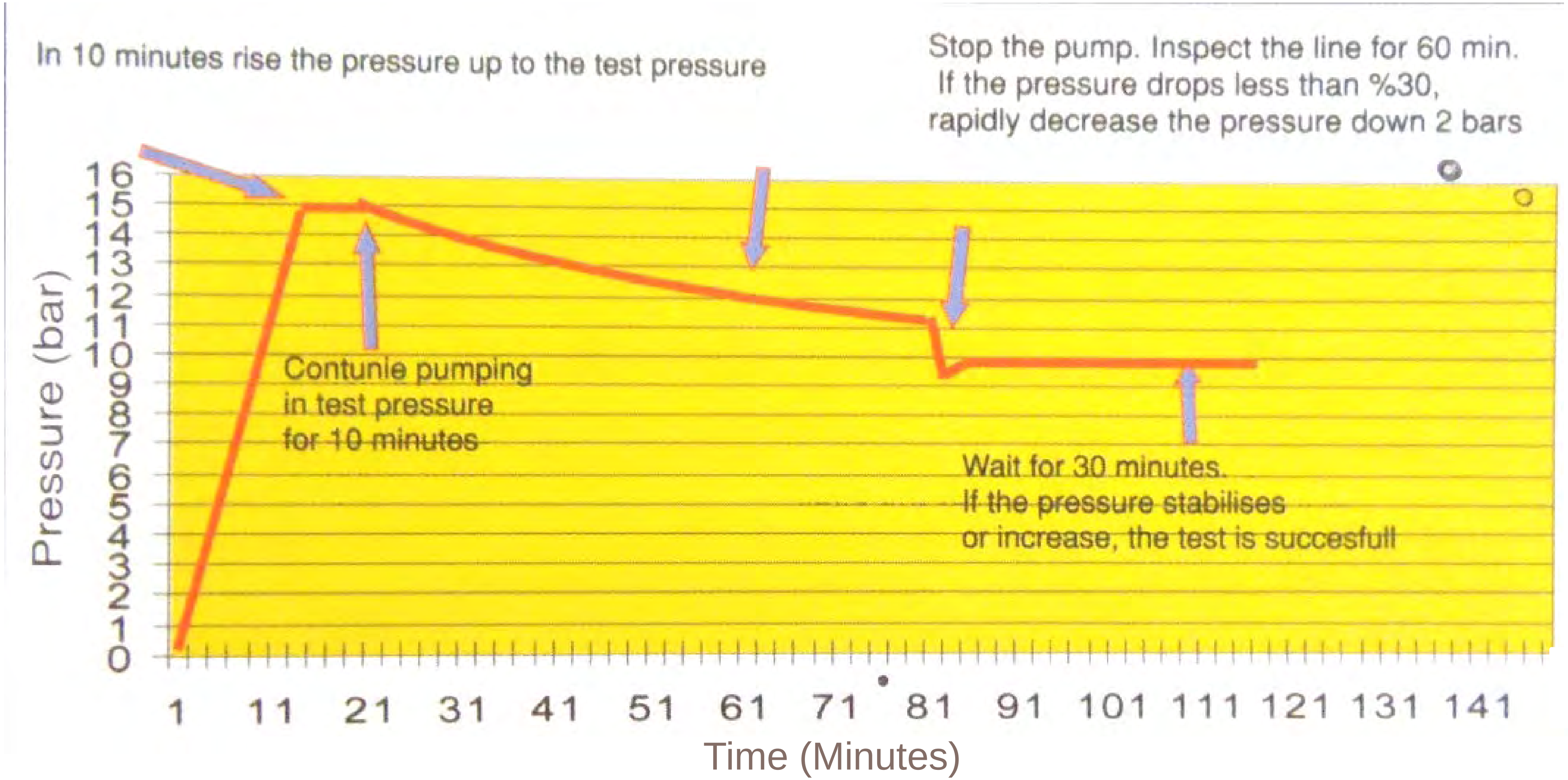
Testing of HDPE pipes

1. Pressure Drop Method



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Testing of HDPE pipes

2. Water Loss Method

After 60 minutes (same as for Pressure Drop Test):

- Measure Vt = volume coming out of pipe when reducing pressure by 2 bar
- Calc ΔVmax:

$$\Delta Vmax = 1{,}5 \cdot V \cdot \Delta p \left[\frac{1}{E_W} \cdot \frac{D}{e \cdot E_R} \right]$$

Where E_W = Modulus of water (2,0 GPa)

E_R = Modulus of HDPE (0,8 GPa)

If Vt ≤ ΔVmax , then "OKAY"

Joining HDPE Pipes with Different Wall Thicknesses

Joining HDPE Pipes with Different Wall Thicknesses

EXAMPLE:

- A contractor wants to use segmented bends in a pipeline
- Fabricated fittings must be de-rated by 40%
- Therefore thicker pipe has to be used to make the segmented bends

BUT:

You cannot butt weld pipes of different wall thicknesses, eg the main pipe and the fabricated fitting

WHAT TO DO?

Joining HDPE Pipes with Different Wall Thicknesses

SOLUTIONS:

1. Use flanged connections

2. Use moulded fittings (do not have to be de-rated)

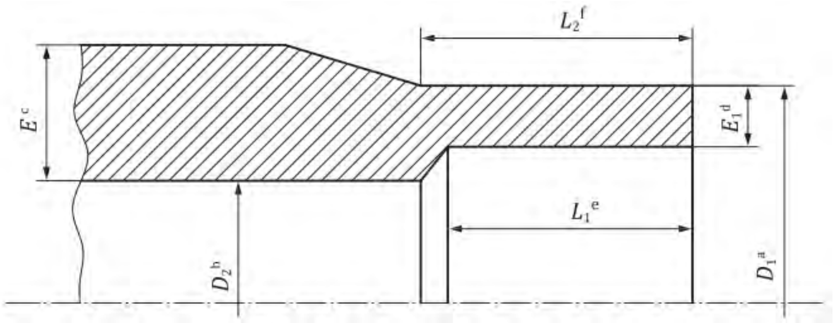
3. Use electrofusion couplings

4. Machine the ends of the fabricated fitting such that the thickness, OD and ID matches the main pipe

   - refer to ISO/FDIS4427-3 : 2019 (Part 3: Fittings)

Joining HDPE Pipes with Different Wall Thicknesses

From ISO/FDIS4427-3 : 2019 (Part 3: Fittings):



Key

D_1 mean outside diameter of fusion end piece

D_2 bore comprising minimum diameter of flow channel through body of fitting

E body wall thickness of fitting

E_1 fusion face wall thickness

L_1 cut-back length of fusion end piece

The standard dimensions are required for correct

- accommodation of the butt welding clamps
- correct heat soak for an effective butt weld

Technical Assistance

1. SAPPMA http://www.sappma.co.za/download.asp
   (not free to non-members)

2. http://www.gfpiping.com/ActiveContent/PE100-TechHandbook-PDF.pdf

3. Ask Google!

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Questions and Answers

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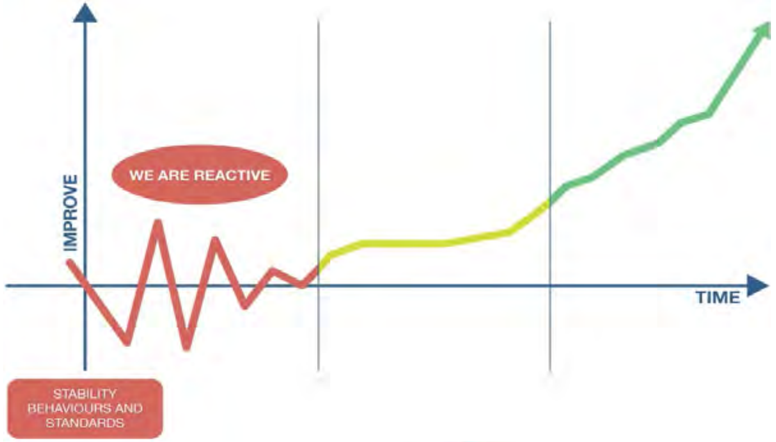
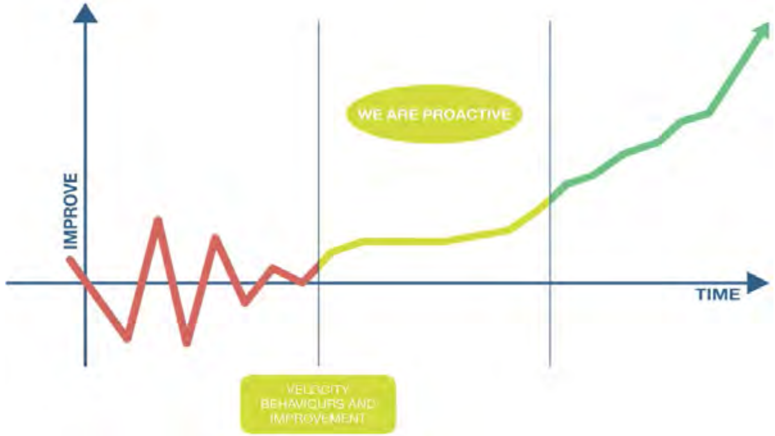
It brings Together

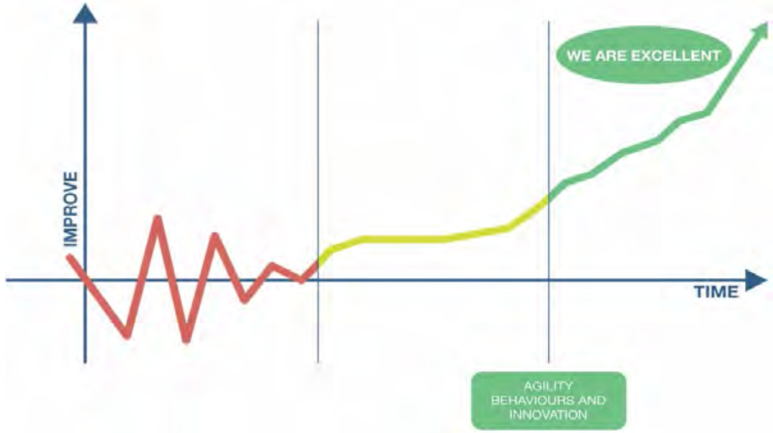
Local Needs

International Support

Satisfied End users







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Introduction to Member Categories

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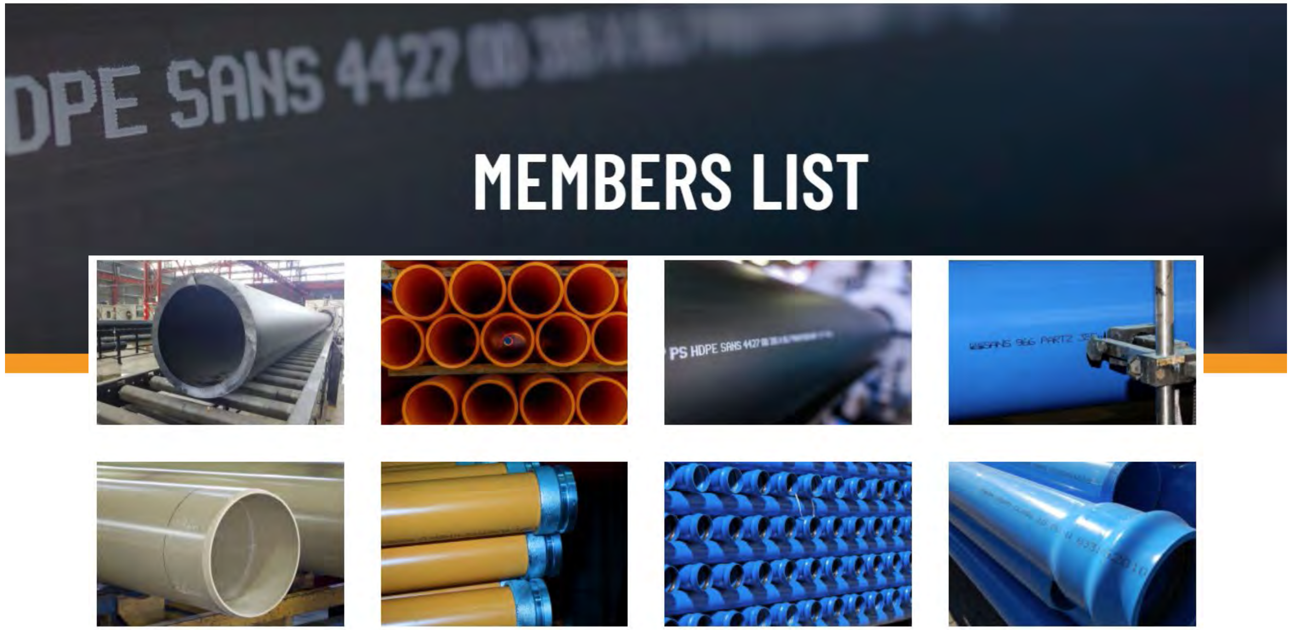
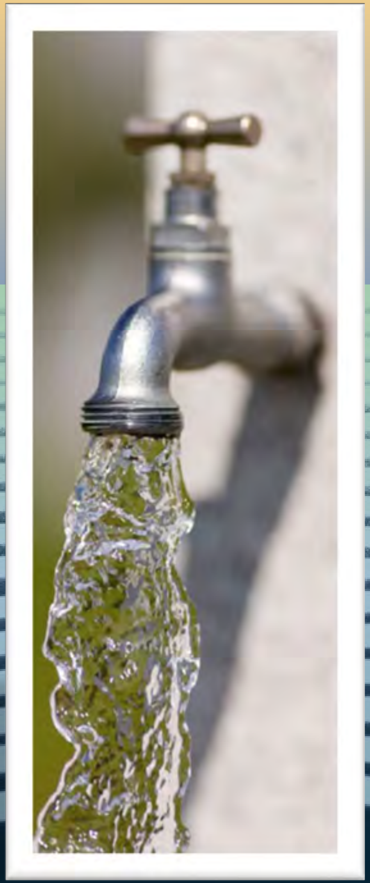


PIPE MANUFACTURERS	POLYMER MANUFACTURERS	SUPPLIERS
CERTIFICATION BODIES	SPECIALISED MANUFACTURERS	INDIVIDUAL MEMBERS

"Someone's sitting in the shade today because someone planted a tree a long time ago."

Warren Buffett



IFPA
INSTALLATION AND FABRICATION PLASTICS PIPE ASSOCIATION

SAPPMA
southern african plastic pipe manufacturers association

Questions and Answers

ian@sappma.co.za
admin@sappma.co.za