Stainless flexible service line

Simply fit and forget

water | team stainless

Contents

Stainless partially corrugated tube (SPCT)

SPCT – for proven and best water loss reduction

Stainless steel service lines have proven performance across millions of installations. SPCT offers:

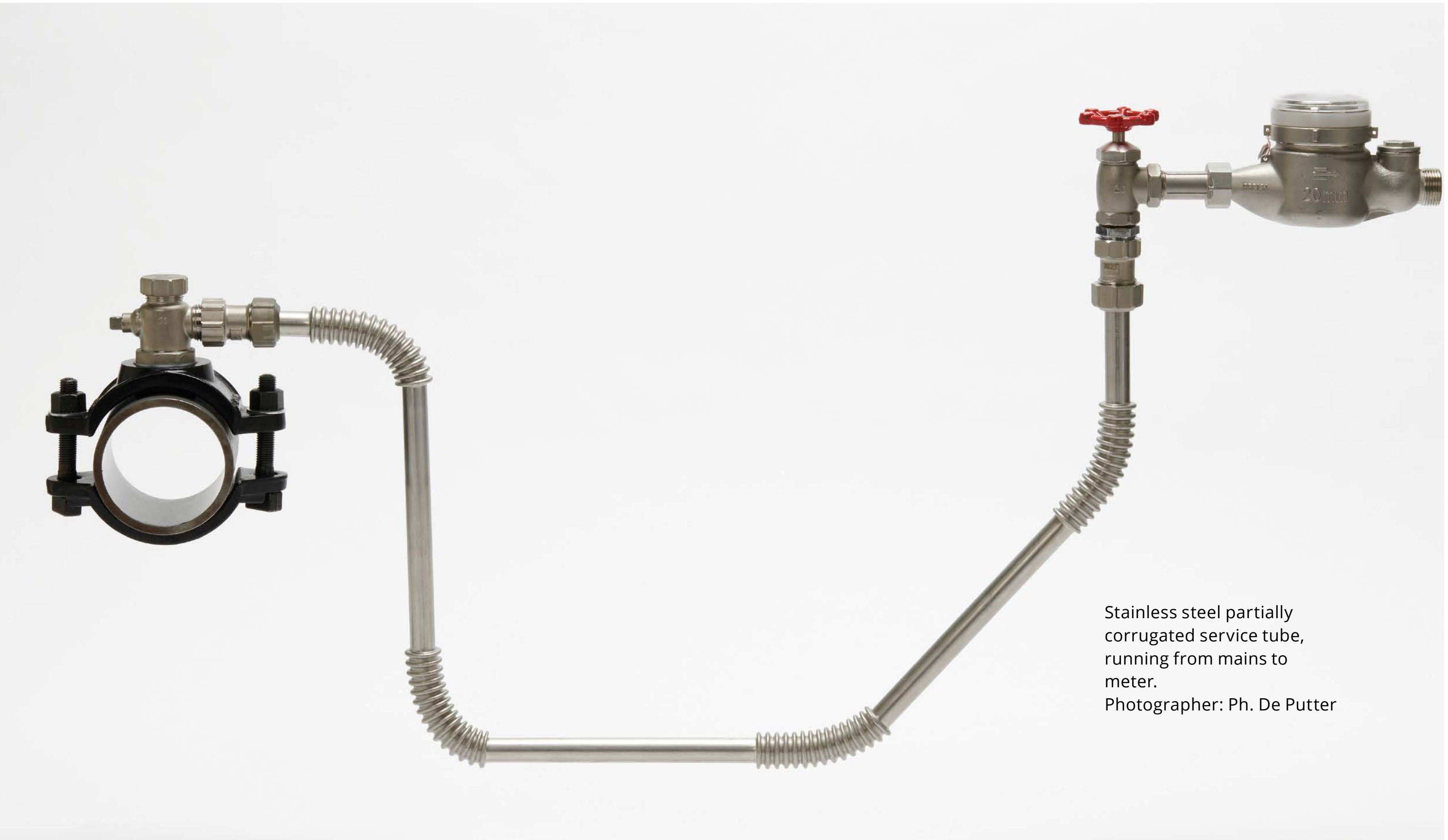
- Proven water loss reduction;
- Extraordinary service life – more than 100 years, without ageing or change of properties throughout the lifespan;
- Safe, impermeable, non-reactive service, ensuring the highest quality water;
- Strength, toughness, resistance to mechanical damage as well as extreme cold and heat;
- Easy, fast installation with flexible tube and minimal number of fittings;
- Compliance with regional and international quality standards.

Once and for generations to come, SPCT is a robust solution for addressing water loss and water quality.

The advantages of SPCT

Stainless steel is recognised as safe and hygienic. It is the material of choice in the global water processing industry and has had a reliable track record that spans decades. It is corrosion resistant, strong, and durable. SPCT is made flexible through corrugations that absorb and resist seismic movement, soil settling and traffic loading. In most cases it will withstand accidental mechanical damage by digging equipment. It is ductile at very low temperatures, meaning SPCT will not rupture even if water freezes inside the pipe. And it is heat resistant in the case of fire. It is easy to put in place, formable at each corrugation and allows for one-length, connection-free installation.

Type 316 stainless steel tube is suitable for all but the most aggressive soils, resisting corrosion and preventing ingress of soil contaminants such as hydrocarbons. In addition, stainless steel is 100% recyclable, with no loss of quality. The advantages result in lowest overall cost to own and operate. Thanks to their resilience and longevity, they reduce not only water loss, but also the costs related to expensive repair cases (including excavation and surface reinstatement), and CO_2 emissions, contributing significantly to sustainable asset management.



Stainless steel partially corrugated service tube, running from mains to meter.
Photographer: Ph. De Putter

Safe and hygienic

No leaching

SPCT is made from Type 316 stainless steel. The leaching of metals from the surface of the stainless steel in potable waters is negligible and will easily meet water quality standards around the world, such as Water UK's Industry Guidance Note [Ref. 1]

Impermeable

Unlike non-metallic materials, stainless steel is impermeable and will not allow soil contaminants, such as herbicides or hydrocarbons, to migrate into the water. This is true for the life of the installation.

Improved water quality

Type 316 stainless steel is resistant to free chlorine up to 5 mg/l, which is the upper limit of the WHO potable water standards. Stainless steel does not react with disinfectant, ensuring sufficient residual chlorine at delivery. Its smooth surface will not attract microbial growth and facilitates cleanability. Turbulent flow caused by the tube corrugations also helps prevent biofilm development and the settling of deposits (Note: for example, in Tokyo, a flow rate of two metres per second results in no deposition).

No taste, odour or turbidity problems

Stainless steel does not impart taste or odour to the water and will not cause turbidity.

Preapproved for water use

Stainless steel is a preapproved material for water use in, for instance, the United States (through ANSI/NSF 61) and the United Kingdom (DWI Regulation 31). In addition, stainless steel is the preferred material for food and pharmaceutical processing, with many design standards nominating these materials (such as the EHEDG and 3A standards) in all parts of the world.

Manufactured to standards

To ensure appropriate quality and safety, SPCT is currently manufactured to the following standards:

Japanese Standard *JWWA G119 Corrugated stainless steel tubes for water*;

Taiwanese Standard *CNS 15604 G 3276 Corrugated stainless steel tubes for water supply*;

Korean Standard *KWWA D 118-2058 Corrugated stainless steel tubes for water works*.

In addition, standards have recently been developed in China and the United States:

ASTM A1119/A1119M Standard *Specification for welded partially corrugated tube for potable water and general service*;

Chinese Standard *T/CADBM 24 Partially corrugated stainless steel tubes for water supply.*

There is a range of fittings standards to complement these standards.

Leak resistant

Minimal number of joints

Most leaks in service lines occur at joints. SPCT is simply bent at the corrugations to fit the installation, reducing buried fittings and joints. For service lines which are longer than the standard four metres, SPCT lengths can be orbitally welded in the shop or joined with earthquake-resistant or other fittings in the field.

Flexible and strong

The corrugations in the SPCT are flexible and the system, including the fittings, is strong and resilient,

SPCT is simply bent at the corrugations to fit the installation, avoiding buried fittings and joints.

Single SPCT lengths can be orbitally welded into coil and can be installed in a trenchless way.

accommodating:

- Significant ground movement from traffic or machinery vibrations;
- Soil settlement or expansion, cave-in, hillside creep and erosion;
- Freezing and thawing;
- Wetting and drying of clay soil;
- Landslides, earthquakes, and liquefaction.

It is also resistant to most accidental damage by digging equipment.

Corrosion and erosion resistant

Type 316 stainless steel is resistant to corrosion in almost all types of soils and to all types of drinking water. It is resistant to erosion in high velocity water up to 40 m/s.

The more than 40 years' experience of the city of Tokyo prove this point. The Tokyo Bureau of Waterworks is not aware of corrosion cases with its Type 316 stainless steel tubes and fittings. Moreover, they have fewer than 0.2 leakage cases per 1000 stainless steel service connections per year, even though about 70% of their stainless steel service lines are 30+ years old, as of 2023.

Similarly, Taipei has been installing stainless steel service lines for nearly 20 years. By 2020 they had found an average of only 12 leaks related to stainless steel service lines per year. At about 200,000 stainless steel connections, representing 64% of all service lines, that corresponds to a very low 0.06 leaks/1000 service connections/year. For comparison, a rule of thumb is that well managed utilities have around 1 leak/1000 service connections/year.

Resilient, strong and ductile

Stainless steel is a robust solution for service lines. It is strong and among the most ductile materials with an elongation greater than 40%. These factors combined ensure no cracking occurs when deformed, and mechanical damage from scratching or gouging is not a problem. Yet, the design of the tube makes it flexible and with that quick and easy to install.

Let's put that in perspective:

Strength comparison

Material	Yield strength (annealed)	Ultimate tensile strength (annealed)
316 Stainless steel	205 MPa	515 MPa
Copper	70 MPa	220 MPa
Plastic (PEX)	19.3 MPa	26 MPa

The design of fittings and tube, as well as the ductility and strength of stainless steel result in a strong and resilient connection.

Higher strength also means lighter sections can be used compared to copper.

Low-temperature resistant

Type 316 stainless steel remains tough and ductile down to very low temperatures; it never becomes brittle, neither at low temperatures nor over time, as some other materials do. Thanks to its high strength, which increases with decreasing temperature, and good low temperature ductility, it will not split, even at very low temperatures and can withstand increased internal pressure of any water transition to ice. In fact, Type 316 and other austenitic stainless steels are commonly used as construction materials in cryogenic applications, at temperatures well below those encountered even in the coldest climates. To avoid freezing and blocking of the tube in regions where low temperatures occur, above ground, outdoor tubes should be insulated or heat traced.

The SPCT system includes both expansion-type and press-fit fittings, which in turn both depend on elastomer seals to maintain system integrity. The commonly used elastomer, Ethylene-Propylene Diene Monomer (EPDM), can be successfully used at temperatures as low as -50°C before the plastic embrittles. EPDM is one of the better performing elastomers in this regard, although Butyl Rubber (IIR) and Natural Rubber (NR) are also adequate. Note that some older plastic pipe, such as uPVC, may have a Ductile/Brittle Transition Temperature (DBTT) higher than EPDM and may have potential bursting issues in extreme weather conditions.

Pressure rating

Components used for water supply are expected to meet the pressure requirements of the supply system, with a good margin for pressure spikes that will inevitably occur from time to time. The Table below shows the pressure rating of the SPCT and some typical fittings which show that the MAWP for each is well above any pressures normally found in operating water supply systems.

Maximum allowable working pressure (MAWP)

Component	MPa	psi/bar
SPCT	1.0	145.0/10
Tapping saddle and valve	0.75	108.8/7.5
Expansion fitting	1.0	145.0/10
Press-fit fitting	1.0	145.0/10

High flow rate resistant

Whilst PEX has been stated to be suitable up to 3.65 m/s and copper is recommended not to exceed 2.44 m/s (CDA), stainless steel is fine up to 40 m/s.

High-temperature and fire resistant

Type 316 and similar stainless steels are preferred for high-temperature applications and where fire resistance is needed. They have good strength and resistance to corrosion and oxidation at temperatures up to 900 °C. Under conditions involving uncontrollable fires, Type 316 stainless steel and similar, outperform other materials. There is no possibility of ignition of stainless steels. The surface of the metal is inert and stable when exposed to almost all flames and heat sources, avoiding detrimental pressure drops in the system due to escaping of water and "inhalation" of toxic gases into the system.

UV resistant

Stainless steel is not affected by sunlight exposure. In fact, stainless steel is a standard construction material for UV water sanitising equipment.

Rodent resistant

Rodents do not damage stainless steel.

Low thermal expansion

The coefficients of thermal expansion for Type 316 stainless steel and copper are virtually identical and are ¼ to 1/10 lower than those of different plastics used in water service at operating temperatures. For example, between 0 °C and 20 °C, a 10 m length of straight Type 316 stainless steel tube will expand 3.3 mm, whereas the same length of HDPE pipe will expand about 30 mm.

Durable

Chloride resistant

Type 316 stainless steel can handle chloride levels of up to 1,000 mg/l in cold water and 250 mg/l in hot water. [Ref. 2] This covers all drinking water that complies with World Health Organisation (WHO) guidelines.

Chlorine resistant

Chlorine is often used for disinfection. Type 316 stainless steel is suitable for use with a constant free chlorine residual concentration of 5 mg/l [Ref. 3], which again is the upper limit in WHO guidelines. For shock treatments, Type 316 stainless steel can handle much higher chlorine doses for shorter periods, 25 mg/l for 24 hours for instance.

Soil corrosion resistant

a. Type 316 stainless steel is resistant to most soils. Scientific research over many decades has supported stainless steel use in soils. In general, Type 316 stainless steel is suitable for direct burial in soils matching the following conditions:
   - pH > 4.5;
   - Resistivity > 2,000 ohm.cm;
   - Chlorides < 1,000 ppm.
b. Most soils fit these criteria. Some examples that would need attention include acid sulphate or high chloride soils. Under these circumstances wrapping is recommended.

pH resistant

Type 316 stainless steel is resistant to low pH water or foodstuffs and is also resistant to highly alkaline pH, well beyond the WHO guidelines.

Galvanic corrosion

Stainless steel is ordinarily at the cathodic (noble) end of the galvanic series, just above copper and its alloys. The potential difference between stainless steel and copper is small (<100 mV) which means there is little driving force for galvanic corrosion to occur.

For SPCT and any copper or copper alloy fittings, the internal electrolyte will be low conductivity tap water which lessens the corrosive effect. Similarly, any externally induced galvanic corrosion in buried environments between stainless steel and copper alloys will be minimal. The most probable galvanic couples in a Type 316 grade SPCT system will be between the stainless steel tube and copper and brass or bronze fittings. These couples generally don't present any corrosion issue when the two materials are in contact above ground or in a meter box.

However, it is best to avoid such couples for buried connections by using stainless steel fittings. Different grades of stainless steel in contact do not present galvanic corrosion issues of any practical significance. However, both copper alloys and stainless steel must be insulated from ductile iron or steel mains by means of a suitable insulated tapping connection.

Stray currents

Stray current corrosion is material independent and stainless steel is no more or less affected than copper, cast iron, galvanised steel or any other metal or alloy. As SPCT is intended to be used from main to meter connections where the main is either plastic or the tapping saddle itself is fully insulated, any stray current effects are unlikely.

Earthing (also known as grounding)

In many countries, each building or residence has an earth stake installed to drain any fault current from the system, i.e., 'earth' it. Earth stakes in some jurisdictions have been 'bonded' with a copper strap to the metallic plumbing system (lead, copper, or galvanised steel) as redundancy. This is not generally advised by the local water utility.

Stainless steel is no more or less affected by stray currents than copper, cast iron, galvanised steel or any other metal or alloy.

Elastomers

For the SPCT systems, several synthetic elastomers are available for either 'O' rings or seals. The table below gives a summary of the main elastomer types and their properties for use in the SPCT system [Ref. 4].

Limiting physical properties			
Common name	EPDM	Butyl (IIR)	Nitrile (NBR)
Hardness range (IRHD)	30-85	40-85	40-100
Maximum continuous temperature	130 °C	120 °C	100 °C
Water and steam resistance	Excellent	Good	Good

Both the 'O' rings and seals used in the press-fit and sleeve-in fittings specified for SPCT have very little surface area in contact with either potable water or external soil. The elastomer exposure conditions, together with the fact that the polymers are in compression, not tension, should mitigate against early failure. In addition, the service life for natural rubber is 100 years so it is reasonable to predict a similar life expectancy for better formulated elastomers like EPDM.

Cost effective

Whilst SPCT has a higher initial cost than some competing products, its lower life cycle cost and its impact on lowering other network operation costs have been demonstrated in the cities where it has been used for decades.

- Tokyo has 2.2 million water connections, distributing 1.54 billion m^3 of water in 2018. It was determined that 97% of repair cases are service piping related. Tokyo started a program using stainless steel service pipe in the early 1980's (which was changed to partially corrugated tubes in 1998) as well as seismic resistant ductile iron mains while improving leak detection, to reduce their water loss rate.

  The program resulted in reduction in water loss from 260 million m3 (15.4%) in 1980 to 50 million m3 (3.2%) in 2018.
- Reduction of repair cases from 69,000 per year to 8,000 per year. The repairs are now almost entirely from legacy infrastructure with stainless steel repairs just a few hundred a year.
- The total savings correspond to more than USD 500 million/year, based on the following assumptions that 210 million m^3 water saved x USD 2/m^3 = USD 420 million/year plus 61,000 fewer repair cases x USD 2,500/case means USD 152.5 million/year.
- The stainless steel service pipes are recognised as the largest contributor to the cost savings.

SPCT's materials performance, service life and costs of service lines are increasingly understood and compared. Considering the attributes of stainless steel, notably its inherent corrosion resistance, long service life and maintenance friendly nature, life cycle costing proves an appropriate tool to assess its long term economic benefits.

The page 14 Annex details the outcome of a 2022 life cycle cost (LCC) study, looking at both stainless steel and polyethylene. The stainless steel solution comes out cheaper than polyethylene after only 16 years and is 27% cheaper over the entire 100 year service life. The outcome of this LCC example is dependent on the assumption that the majority of leakage problems originate from the service lines, not the mains, as was the case in the Tokyo and Taipei examples.

Easy to install and operate

Installation basics

The site preparation is no different than for other materials. After the tapping saddle is installed, the valve is closed and the main is tapped. The SPCT is then bent into the required shape and connected to the tapping valve. Depending on the valve design, this is done directly at the outlet or with the help of a saddle socket that is screwed onto the outlet. At the meter end, the tube is cut to length with a standard hand-held stainless steel cutting tool and connected to the meter valve with the help of a valve socket that is screwed into the meter valve. SPCT can be bent without any tools for most sizes, otherwise a simple bending tool is available. It is good practice to pressure test the installation before back filling.

Most installations will not require joints or unions. This makes installation rapid and secure. However, if more than 4 metre length are required two or more lengths of tube can be joined with a socket or preferably lengths of tube that can be orbitally welded together in the shop to create a longer tube without impacting either mechanical properties or corrosion resistance. In the latter case, the tube should be "coiled" for transport with as large a coil diameter as possible, to minimise cold working the corrugations before installation. Trenchless installation can be performed with orbitally welded SPCT.

Being strong and corrosion resistant, Type 316 stainless steel is much more forgiving of poor trench preparation, back fill quality or mechanical damage, than competing materials. (Note: good standards are recommended and proper bedding and backfilling will lead to even longer lifetime)

Typically, site installation requires:

- No welding;
- No threading on pipe/tube;
- No inserts;
- No flaring.

The SPCT will typically be delivered with a protective plastic sleeve and should be stored in a covered and dry location. Storage away from weather and sun ensures no degradation of the plastic or contamination of the surface. The product is very corrosion resistant, but cleanliness before and during installation will ensure maximum hygiene and performance.

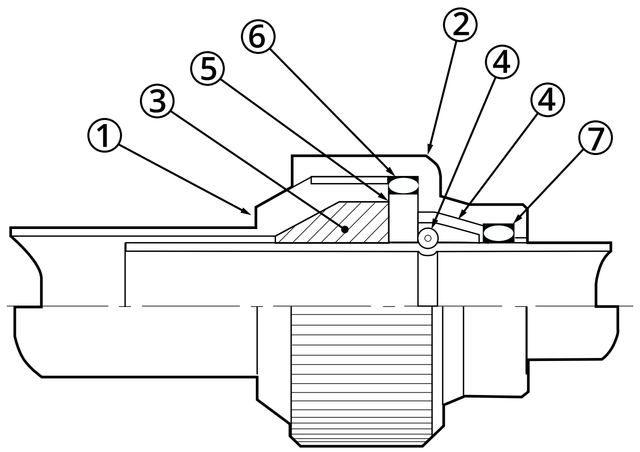
Handling SPCT requires no special knowledge. But care should be taken to avoid bending the corrugations before installation, damaging the ends of the tubes, or contaminating the surface with other materials and especially avoiding contact with carbon steels.

Making connections

As with all materials, and independent of the type of fitting, cleanliness is a must. Remove all contaminants and ensure that the tube end is free of any mechanical damage or burrs before starting assembly.

Following are only a few possible fittings that can be used to connect SPCT

Expansion or sleeve-in type fittings

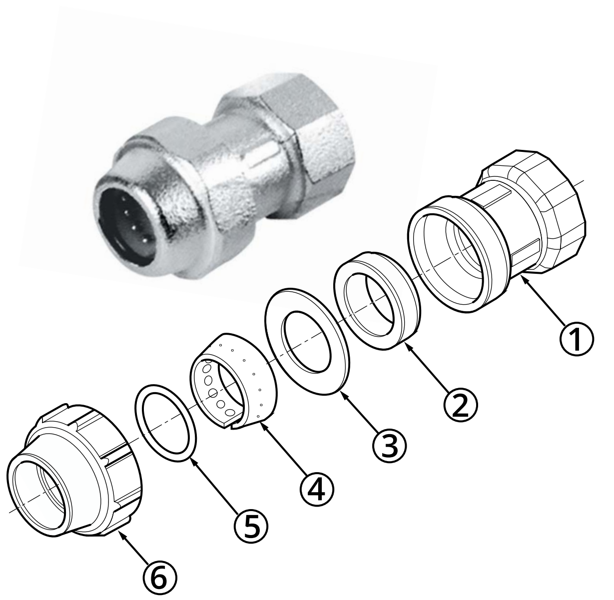


Side view of an expansion type fitting as used in Japan. [Ref. 5]

1) Body
2) Nut fastener
3) Seal
4) Lock
5) Seal guard
6) Dust-proof sealant
7) Dust-proof sealant

Sleeve-in tightening torques			
Size	Distance from end of SPCT (mm)	Depth of groove (mm)	Minimum tightening torque (Nm)
20–25	49	0.75	70
30–50			120

Sleeve-in fittings provide the best pull-out strength and are therefore particularly suitable for seismic areas or other situations with elevated mechanical loads. The installation is quick and easy. The fitting is simply pushed over the tube end and tightened, not requiring disassembly or special tooling.



Expansion type fitting

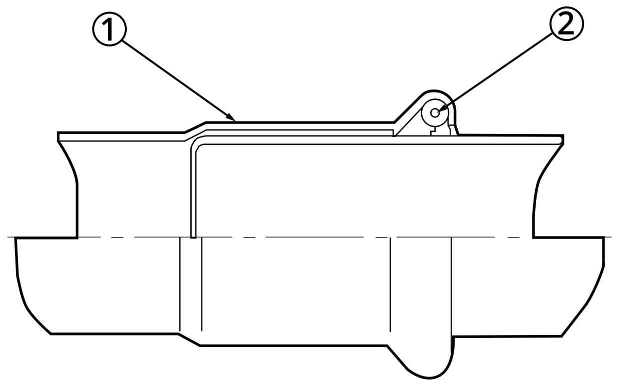
1) Body
2) Packing
3) Washer
4) Ball Guide
5) O-Ring
6) Nut

Picture and drawing sources from Hi-Sten.

Sleeve-in fittings can be installed with or without groove. Adding a groove on the SPCT, can improve the mechanical strength of the joint. If a groove is used, the distance from the pipe end is marked, and the groove is made to the appropriate depth using a specialised groove-making tool, similar to a standard hand-held tube cutter. Guidance on the appropriate distance and depth of the groove can be found in the table on the left. The SPCT is then inserted into the fitting and the groove is aligned with the locking mechanism by hand tightening the nut. Once the fitting is in place, the nut is tightened using a wrench. It is recommended in the JWWA standard that the nut is torqued to the levels shown in the table below.

Press-fit fittings

The term “press-fit” refers to a joining method for the SPCT by means of fittings which are mechanically pressed with specific tools. This method of mechanical joining of stainless steel is both fast and economical. However, the pull-out force is lower than for the other two types of fittings. Press-fit joints rely on the sealing capability of an elastomeric ‘O’ ring, gasket or seal. The equipment required to make the joint are a set of jaws, designed specifically for the fitting type being used, and a hydraulic pressing tool. The pressing tool may be battery or electrically powered. The length of insertion of the SPCT into the fitting depends on the fitting selected and the manufacturer’s recommendations. Please note some jurisdictions may not allow this type of fitting to be buried underground.



Press-fit fitting [Ref. 5]

1) Body
2) Seal

Picture courtesy of Viega.

Galling

During installation of threaded austenitic stainless steel components (fittings, fasteners), galling of the threads may occur. Galling is a form of cold welding of the 2 surfaces when sliding against each other. Threads that have been poorly machined or damaged are likely to gall. Use of a suitable lubricant usually prevents galling.

Assembly Issues

SPCT and fittings must be kept clean of any contaminants, e.g. dust and dirt, before and during installation. Ensure the SPCT is deburred after cutting, so the seals are not damaged during assembly. Use cutting tools that are suitable for and used on stainless steel only. Do not use the same tool previously used with carbon steel.

Placing SPCT

SPCT has eight corrugated sections along a standard four metre length; it is theoretically possible to make a bend at each corrugated section. In normal installations bends would be made at the tapping valve, at the bottom of the trench and at the meter valve. It is easy to make a 90 degree bend.

Backfilling trench

It is recommended to use suitable clean sand or granular backfill to encase the SPCT before replacing the soil that was extracted from the trench.

Operating guidelines for SPCT

Disinfecting the water system

It is standard practice to disinfect water storage tanks, reservoirs, and water mains when commissioning or recommissioning, typically with sodium hypochlorite solutions. Service lines are not usually included in disinfection regimes, but Type 316 stainless steel SPCT main-to-meter sections can tolerate continuous free chlorine levels up to 5 mg/l and for short periods higher concentrations are allowable. Therefore, if any disinfection regimes of water mains occur in the vicinity of SPCT systems they should remain unaffected.

SPCT can be bent at each corrugated section. In the lay-out shown, no bends are made at the tapping valve. A 90 degree bend is easily made at the meter connection.

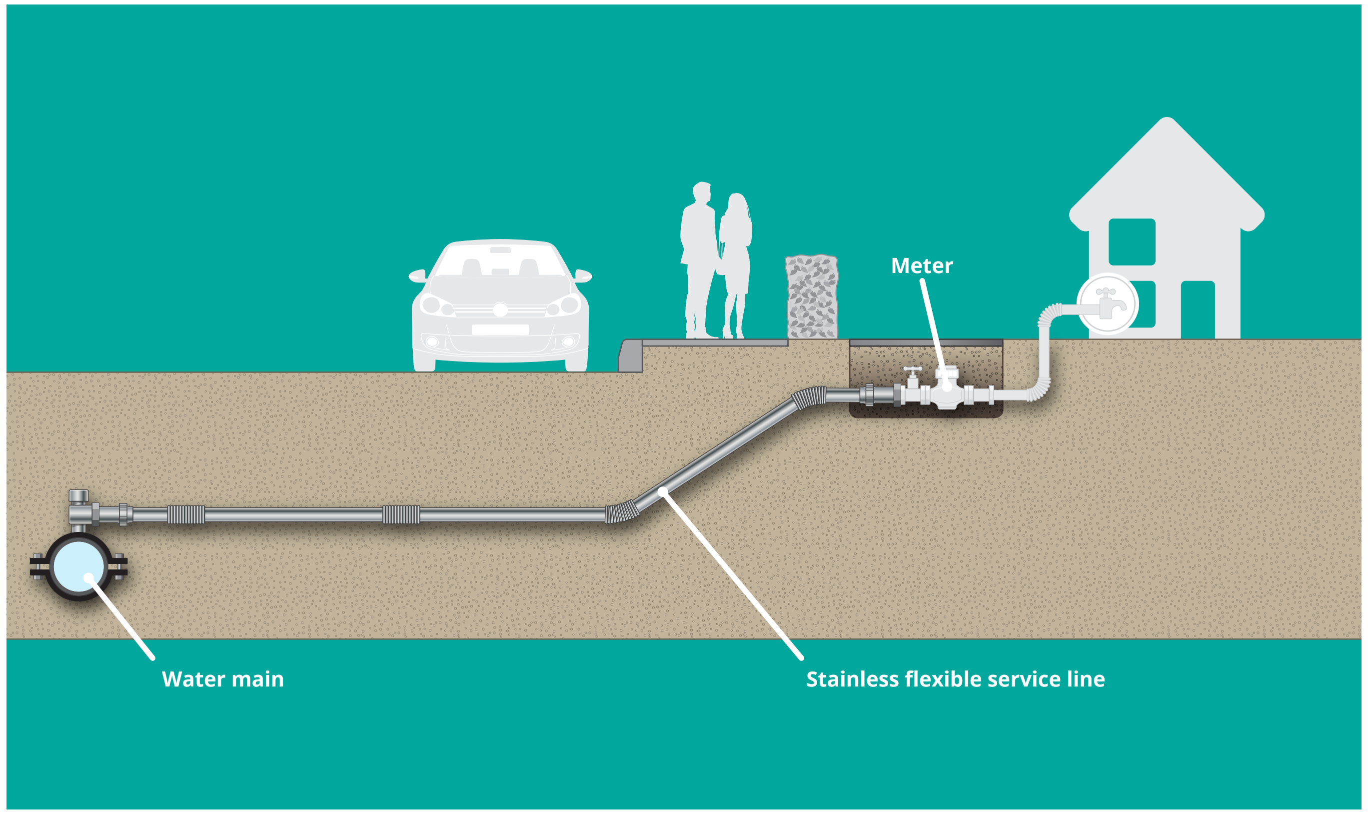
Locating buried SPCT

Tracing SPCT is simple because it is metallic and can therefore be located with standard tracing equipment whilst plastic pipes are difficult to locate.

Leak detection

Traditional leak detection is founded on the principle of listening for the noise created by water escaping from a leak in a pressurised water pipe. This leak noise is conducted more effectively in metals (cast iron, ductile iron, galvanised steel, stainless steel and copper) compared to non-metallic materials (e.g., plastics and asbestos cement). The same principle explains why church bells are made of metal and not plastic. The leak noise, which can range from a hiss to a roar, is conducted along the pipe walls through the water network. Leak detection technicians use this noise to pinpoint the location of the leak. The distance the leak noise travels can be hundreds of metres in metal pipes compared to up to around one hundred metres in plastic pipes although the operating pressure, diameter and material will impact these lengths. Stainless steel pipes therefore require fewer listening points (meters, valves, hydrants) than plastic ones.

Another difficulty for leak detection created by the replacement of metallic pipes with plastic materials is tracing to locate these assets. Accurate distance between leak noise correlation sensors is required for accurate calculation of the leak location. This is determined by onsite measurement and programmed into the leak noise correlator. If the location of the pipe is not accurately known, the correlator accuracy will not be so reliable. Should one day all water meters be equipped with noise sensors, automated leak detection in SPCT service lines will be even easier.



Annex: Life cycle costing

Stainless steel in infrastructure proves to save more costs during the asset's entire service life than any other available material. An LCC (life cycle costing) approach was used to assess the long-term financial benefits of stainless partially corrugated tube for service lines. The total cost of one stainless steel tube – as used in Tokyo - was compared to the total cost of one polyethylene tube (as used in Australia), which represents a widely used material. As stainless steel is expected to last for at least 100 years, this life span was taken as the comparison's timeframe of a worry-free service life.

The costs considered were the following:

- Component and installation cost: acquisition of pipe, saddle and fittings and installation (excavation)
- Operating cost:
  - Maintenance (due to leaks, in which case replacement of pipe is assumed)
  - Scheduled replacement linked to service life expectation
  - Lost water from leakage
- Details about costs and assumptions are available here. [Ref.6]

Costs for both the stainless steel tube and the polyethylene tube were discounted to net present value. The concept of "real interest rate" was used for that purpose. The real interest rate corrects the observed market interest rate for the effects of inflation. Data are listed in the table summary below.

With these assumptions:

- Type 316 stainless steel service line is clearly cheaper than polyethylene over the entire worry-free service life of 100 years, as the diagram below shows.
- More importantly, Type 316 SPCT becomes less expensive after only 16 years already.

From this table, it becomes clear that excavation to install service lines is the most important cost factor. Service line systems that are more prone to leakage will require more frequent excavations. The cost of the hardware is only a fraction of the installation cost. It is therefore important to select reliable materials upfront. Type 316 SPCT entirely delivers on its "fit and forget" promise.

Life cycle cost summary for one water service connection

	316 SPCT	Polyethylene
Component costs	284.31	163.04
Installation costs (mostly excavation)	3,950.00	3,950.00
Total initial costs (today's value)	**4,234.31**	**4,113.04**
Component cost is only 7% (316) or 4% (PE) of the initial cost		
Discounted maintenance costs (100 years)	21.52	138.28
Discounted replacement costs (once for PE)	-	1,088.56
Discounted water loss cost	43.53	564.69
Total operating costs (discounted)	**65.05**	**1,791.53**
Total LCC (discounted to NPV)	**4,299.36**	**5,904.57**

Present value costs - Australia 2021 - all values in AUD
Real interest rate: 2.75%
Desired life: 100 years

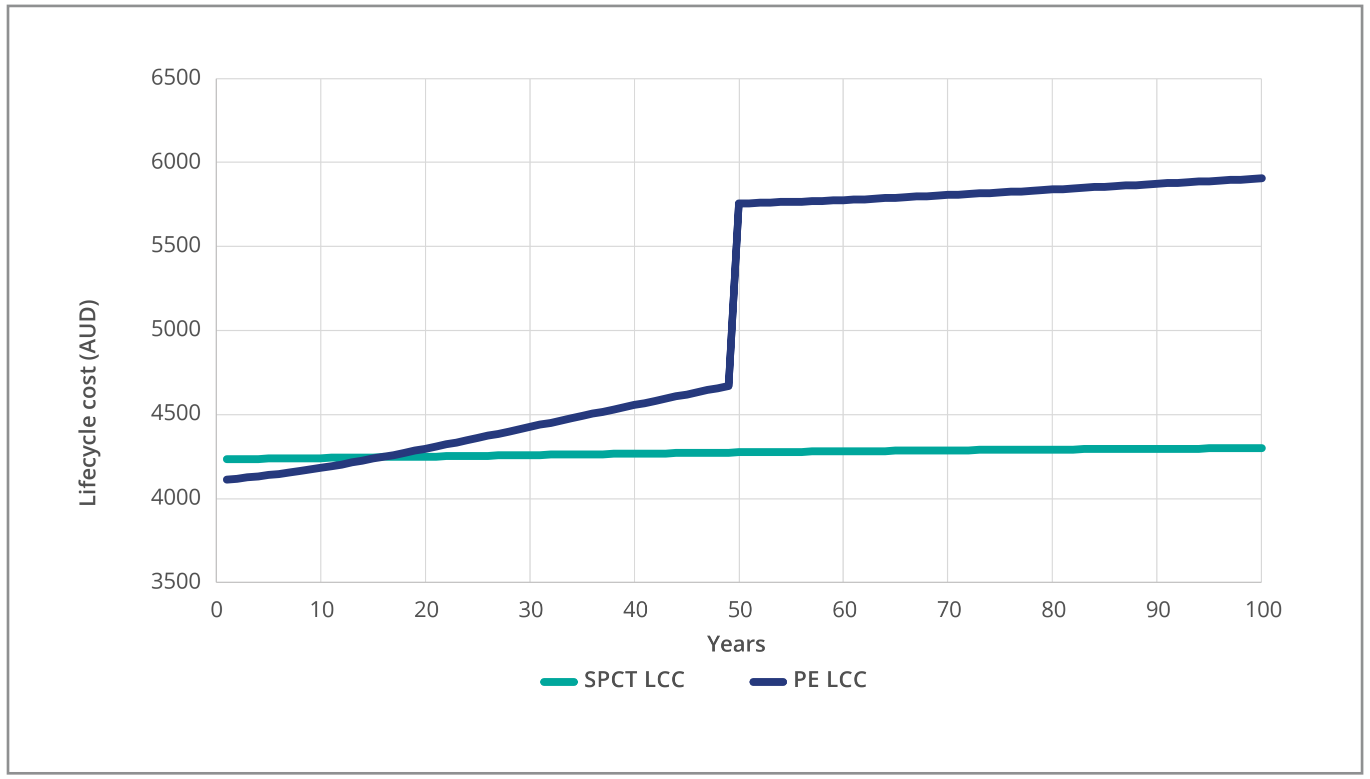
Noteworthy: the 316 solution becomes less expensive than the PE one after only 16 years

The effects of a couple of different assumptions are summarized in the sensitivity analysis table. The "base" scenario corresponds to the one described in the LCC summary table.

LCC Sensitivity analysis

Scenario >	Base	Cost of water at 0.20 AUD/m³ instead of 3.23 AUD/m³	Interest rate at 0.01% instead of 2.75%	PE service life at 25 years instead of 50 years
Stainless LCC	4299 AUD	4258 AUD	4504 AUD	4299 AUD
Polyethylene LCC	5905 AUD	5375 AUD	10658 AUD	8663 AUD
% savings from using stainless	27%	21%	58%	50%
Years to reach parity	16 years	50 years	14 years	12 years

Cost comparison between Type 316 stainless (SPCT) and polyethylene service line over a 100-year service life



References

1. The Steel Construction Institute, Avesta Sheffield and The Nickel Institute "Applications for Stainless Steel in the Water Industry" (IGN 4-25-02, January 1999).
2. The Nickel Institute "Fabricating Stainless Steels for the Water Industry, Guidelines for top performance" – Appendix C p14 (Series N° 11026, October 2005)
3. The Nickel Institute "Fabricating Stainless Steels for the Water Industry, Guidelines for top performance" – Appendix C p15 (Series N° 11026, October 2005)
4. Main source: *James Walker Elastomer Engineering Guide*.
5. JWWA Standard G115-G116
6. The International Water Association, Water Loss Specialist Group "Water Loss 2022 Proceedings - B.1.4 - 316 stainless partially corrugated tube vs. polyethylene for service lines: a cost comparison - B. Van Hecke - The Nickel Institute" - June 2022

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