Stainless Steel - Meeting the needs of the Water Industry

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What are the needs of the water industry?

Equipment which:

- maintains the purity of the water
- is durable and low maintenance
- is cost effective
- has proven performance

Today we will illustrate how stainless steel can meet these needs.

Stainless steels in the water industry

Water treatment

Distribution

Plumbing

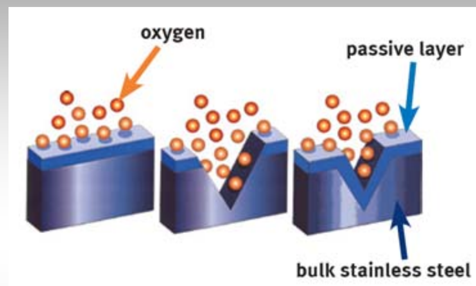
Waste treatment

Structures

- Benefits of using stainless steels in water applications
- The importance of good practice
- Examples from around the world

What is stainless steel?

- Steel containing more than 10.5% chromium
- Chromium reacts with oxygen in the air or dissolved in water to form the protective passive layer
- The passive layer is self-healing (in most situations) if damaged
- Nickel improves characteristics, including formability
- Molybdenum improves resistance to local corrosion



Euro Inox

Maintaining water purity

- Materials should not release substances into the water

Maintaining water purity

- EU Drinking Water Directive (based on former WHO guidelines), weekly averages:
  - Cr < 50 µg/l
  - Ni < 20 µg/l [WHO now revised to 70 µg/l]
- EU pre-normative research pipe rig tests showed Cr and Ni leaching values < 5% of EU maxima

Maintaining water purity

- UK Drinking Water Inspectorate study, 24 hour stagnation tests in 54.5 mm pipe:
  - Cr < 1 µg/l
  - Ni < 2 µg/l
  - "… the use of products made from the specified grades of stainless steel [1.4307, 1.4404, 1.4462 and similar] in contact with water for public supply would be unobjectionable on health grounds."
- Experience confirms low leaching levels

Scottish Hospital

Nickel pickup in water (ppb)

Water analyses taken over a 1250 day (3.5 year) period after installation of stainless steel plumbing

Nickel was in all cases < 20 ppb (EU Drinking Water Directive maximum)

Day	Cold Water		Hot Water
	304 1.4307	316 1.4404	Mixed 304 and 316
0	1.7	0.6	3.8
1	1.1	1.9	4.5
2	1.3	1.9	4.3
3	1.4	1.3	5.5
4	1.7	1.6	5.7
11	1.5	6.1	9.3
18	<0.5	1.1	11.1
25	1.0	0.7	15.4
32	1.1	2.1	14.0
180	1.0	<0.5	2.8
1250	0.6	<0.5	1.2

Mo and Cr < 2 ppb throughout

Approvals to use stainless steels

- Local approvals in EU Member States will be replaced by European Acceptance Scheme
- USA:
  - specified grades approved for public water supply without restriction under ANSI/NSF 61
  - approved under International Building Code
  - approved under International Residential Code
- Local schemes in Australia/New Zealand, China, Malaysia

Maintaining water purity

Metals entering drinking water from treatment or distribution

↓

Waste water treatment

Discharged in water

In sewage sludge

↓

May restrict use of sludge as agricultural fertiliser

Not a problem for stainless steel

Characteristics of Stainless Steel in Use

Characteristics of stainless steels in use

- Excellent corrosion resistance:
  - no general corrosion so no need for corrosion allowance
  - no need for protective coating
  - no need to control water chemistry (except biocide)
  - no need for corrosion protection system
  - water purity is maintained
  - equipment is durable with low Life Cycle Cost
- Tolerance of high flow rates
- Good strength and ductility
- Lightweight design is possible
- Ease of fabrication
- Readily available in many forms
- Fully recyclable and contributes to sustainability

How to benefit from stainless steel

- Follow good practice
- Remember, like most other metals, stainless steel can corrode if not used properly!

Good practice in selection and use

- Best performance when:
  - correct grade for application
  - correct design
  - correct fabrication (off-site if possible)
  - correct installation and commissioning
  - correct operation within design envelope
  - correct maintenance
- Information on good practice is available from stainless steel suppliers and development associations

Grade selection guidelines

Chloride content of the water is most important parameter

Practical experience and tests show crevice corrosion is unlikely if:

Chloride level	Suitable grades
<200 ppm	304 (1.4307), 316 (1.4404)
200 - 1000 ppm	316, duplex 2205 (1.4462)
1000 - 3600 ppm	duplex 2205, 6% Mo superaustenitic, superduplex
>3600 ppm and seawater	6% Mo superaustenitic, superduplex

Other grades with equivalent corrosion resistance may be suitable.

For hot water or to be more conservative, use limits of 50 ppm for 304 and 250 ppm for 316

Maximum Chlorine Cl_2 Levels in Water to Avoid Crevice Corrosion

Types 304 and 316 can resist chlorine levels normally present in domestic water systems

Type 304 (1.4307)	< 2 ppm
Type 316 (1.4404)	< 5 ppm

Shock dosing, such as 25 - 50 ppm free chlorine for 24 - 48 hours, is common practice and has not been found to cause problems. But flush the system thoroughly afterwards.

Stainless Steel Fasteners

ISO 3506 Standard:

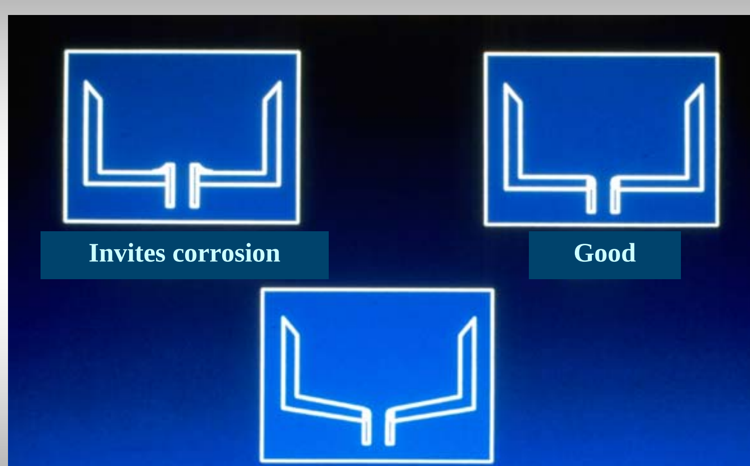
-1: Bolts -2: Nuts

- **304 or 316 stainless**
- **Avoid 303 (1.4305) stainless (‘*free machining*’)**
- **Grades:**
  - **Softened**
  - **Cold- worked**
  - **High-strength**

Design and Fabrication

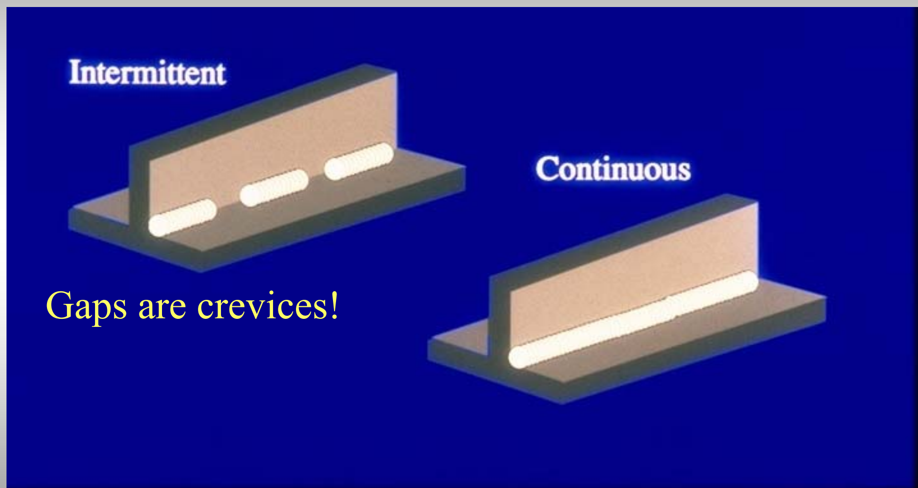
- Minimise opportunity for crevice corrosion:
  - good detailing to avoid sediment in joints
  - welded connections when possible

Tank Centre Drains



Best

Fillet Welds



Crevice corrosion

Crevice corrosion can occur when the wrong grade of stainless steel is selected for the conditions

Type 316 used in a coupling for seawater. It was successfully replaced with a 6% Mo stainless steel.

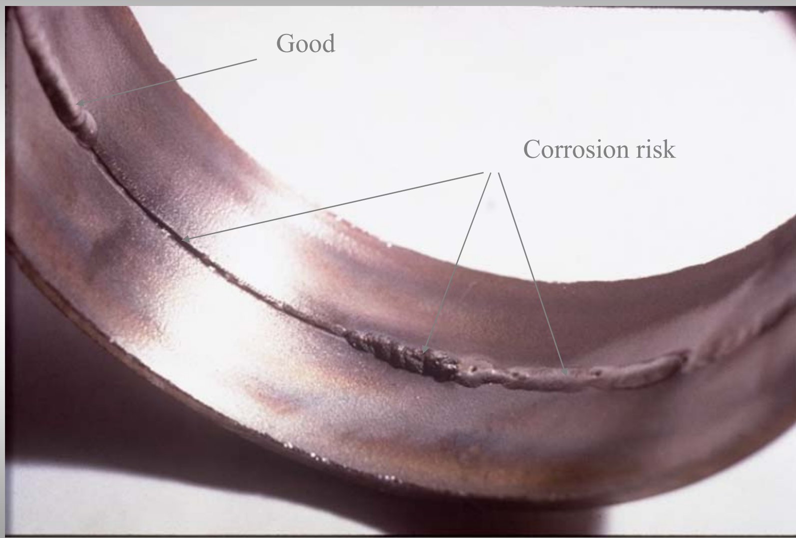
Minimising the effects of crevices

- **Design to avoid crevices**
- **Prefer loose open crevices**
- **Avoid stagnant conditions in raw waters**
  - **Provide good flow and turbulence**
- **Keep crevices dry**
  - **Seal weld**
  - **Seal with mastic**
- **Use good fabrication practice**
- **Use more corrosion resistant grade of stainless steel**

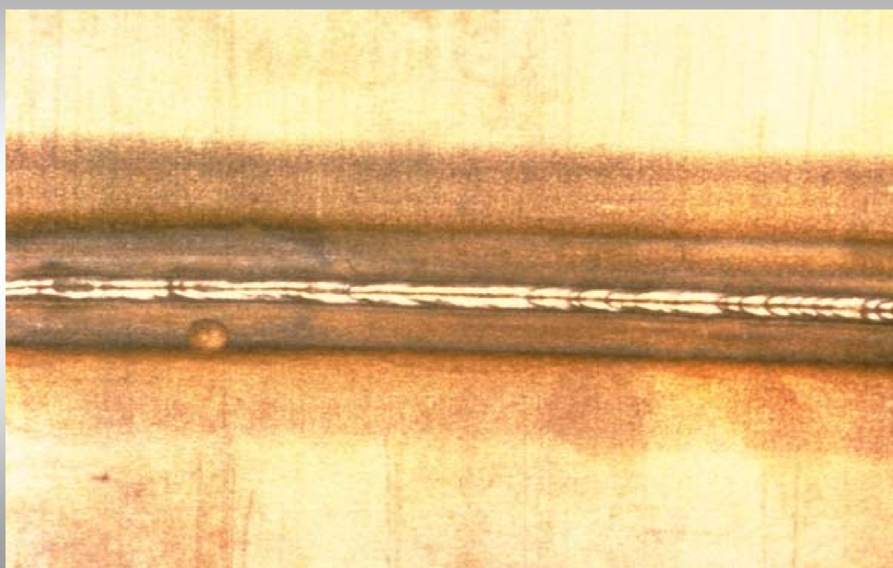
Design and fabrication

- Good welding practice:
  - full penetration welds without defects
  - avoid or remove heat tint

Pipe Welding

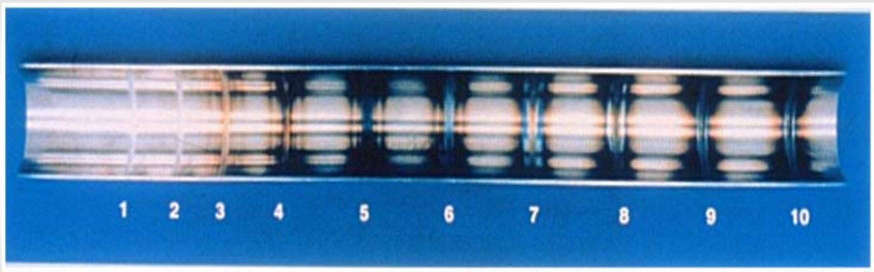


Heat Tint



Heat Tint

10 ppm **Oxygen →** **25000 ppm**



AWS D18.2

Heat tint up to Number 3 is probably acceptable in most water situations

Pickling

Before

After

Pickling

- Chemical treatment to remove metallic contamination and heat tint
- Standard Practice ASTM A 380

Pickling

Spray Pickling

Design and fabrication

- Good housekeeping during material storage and fabrication
  - iron contamination causes cosmetic rusting
    - clients do not like it
    - prevent or remove it

Corrosion of embedded iron in a stainless steel pipe bend

Caused by sparks from grinding nearby carbon steel

Design and Fabrication

- Avoid galvanic corrosion of other metals by use of stainless steel or copper-based fittings or insulate from iron and steel

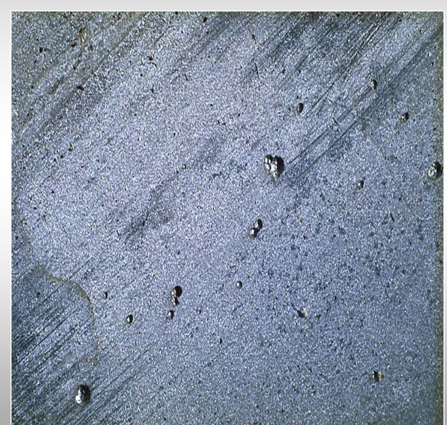
Galvanic corrosion between a carbon steel support ring and the large Type 304 hot water storage tank to which is was welded. The tank was lagged with fibreglass and water leaked into the lagging.

Guidelines to avoid galvanic corrosion

- Use materials of similar electrode potential (eg stainless steel and copper alloys)
- Insulate between the two different metals so current cannot flow
- Where this is not possible, make the key component (eg fasteners) from a more noble material (eg stainless steel)
- Ensure the less noble material (eg galvanised steel) is present in a much larger surface area than the more noble material (eg stainless steel)

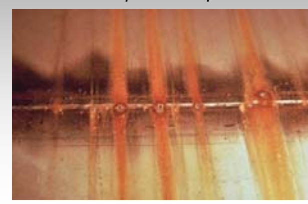
Pitting
Possible causes in waters

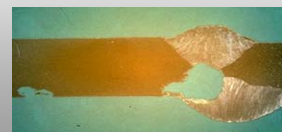
- Surface inclusions (such as MnS) exposed
- Surface contamination (such as embedded iron particles)
- Chloride (Cl^-) levels too high
- Over-chlorination (Cl_2) in treated waters



Guidelines for avoiding microbiologically influenced corrosion (MIC)

Well water left in tank for 3 months





- Some instances of MIC have occurred when hydrostatic pressure tests have been carried out with untreated water which has then been left in the equipment
- Always remove heat tint
- Use drinking water for hydrostatic testing

Handling oxidants

Stainless steels resist oxidants used in water treatment, such as:

- **Chlorine**
- **Ozone**
- **Chlorine dioxide**
- **Potassium permanganate**

Chlorine practices

Care required:

- **Injection areas - do not inject against stainless steel**
- **Excessive dosing - avoid**
- **Where chlorine vapours can collect - vent or wash down or choose a higher grade of stainless steel**

Good practice in selection and use

- Best performance when:
  - correct grade for application
  - correct design
  - correct fabrication – off-site if possible
  - correct installation and commissioning
  - correct operation within design envelope
  - correct maintenance
- Information on good practice is available from stainless steel suppliers and development associations

Guidelines for good practice

- American Water Works Association standards on stainless steel in pipes, couplings, tapping sleeves, flanges and fittings
- Applications for Stainless Steel in the Water Industry, IGN 4-25-02, WRc
- UK – Operating Guidelines and Code of Practice, British Stainless Steel Association: an integral part of approval of stainless steel products by UK Drinking Water Inspectorate
- Germany – DIN 50930
  - Part 4 – evaluation of the corrosion likelihood of stainless steels
  - Part 6 – influence of the composition of drinking water
- France - ASTEE
- Similar guidelines elsewhere would increase correct use of stainless steels

Applications

Screens

Drinking water treatment

Slide gates

Drinking water treatment

316Ti pipework in Germany

Lightweight

Welded and flanged construction

Drinking water treatment

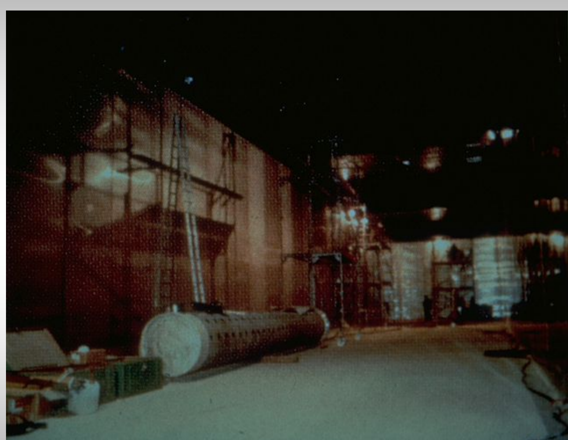
316 for ozone generator, Italy

316L ozone/chlorine mixer, USA

Drinking water treatment

316L granular activated carbon tanks, Italy

Reservoir lining

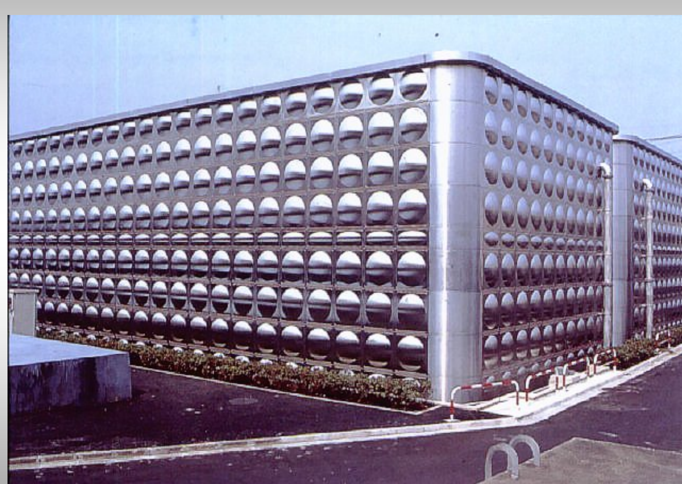


Stainless steel wallpaper lining of reservoir, Remscheid, Germany

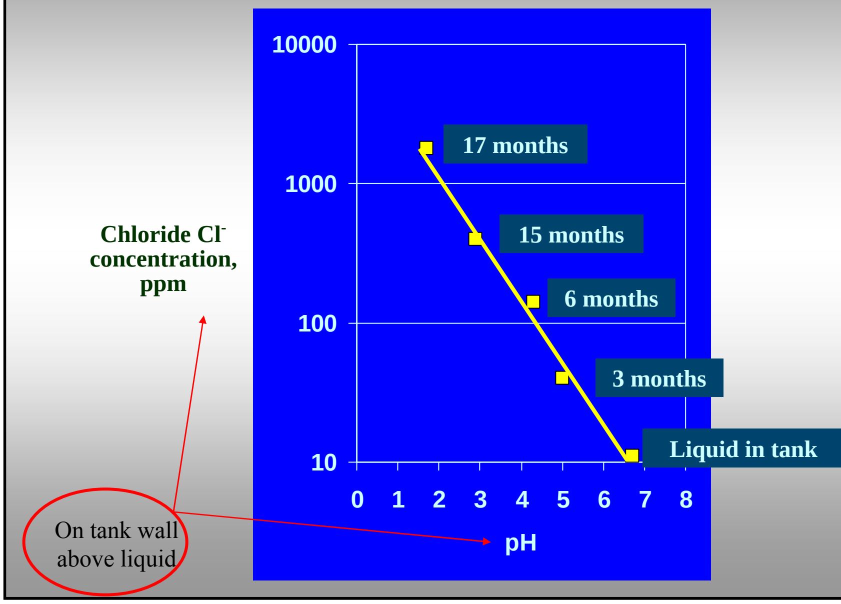
Storage tanks

Centro Inox

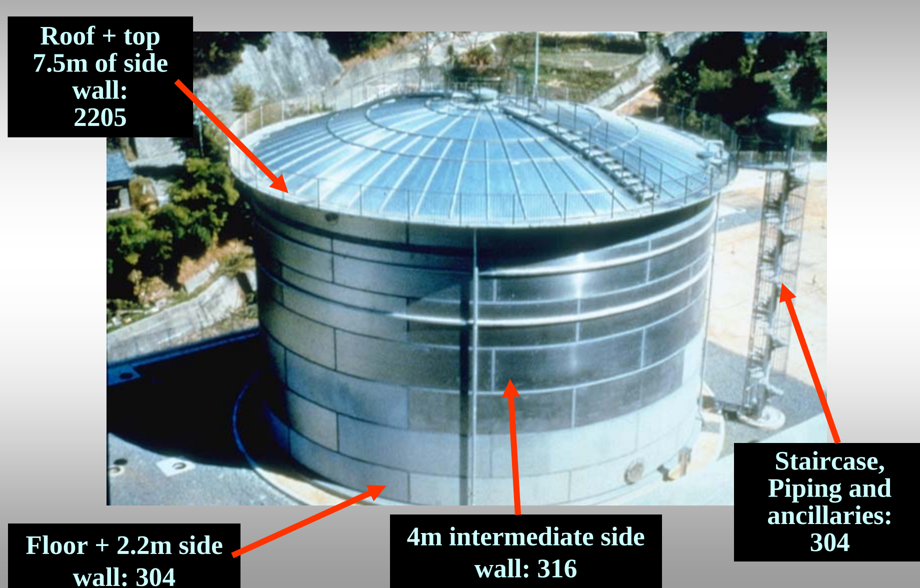
Drinking water storage, Japan



Japanese study showing buildup of chlorides over time in a tank vapour space



Municipal water storage tank – Matsuyama, Japan



Distribution

Karlskoga, Sweden

150 mm pipe replacing cast iron and plastic

- Leak-free after 10 years
- Lightweight means lower cost installation

Cost comparison of distribution piping

Nominal Pipe Diameter Inches	Relative Total Cost Comparison Per Linear Foot* 2000LF Project using 40 foot lengths of S.S. Pipe Pipe Material and Diameter				
	Ductile Iron Class 51	304 Sch. 10	316 Sch. 10	2304 Sch. 10	2205 Sch. 10
6	1	1.03	1.11	1.22	1.45
8	1	1.06	1.15	1.27	1.57
10	1	1.09	1.20	1.34	1.63
12	1	0.82	0.91	1.02	1.26
14	1	0.69	0.75	0.96	0.99
16	1	0.69	0.76	0.97	0.98

* 2003 costs, relative to ductile iron

Distribution pipe

Vancouver, Canada

Grade selection in soil

•No stray currents

•No anaerobic bacteria

•pH>4.5

Résistivité (Ω.cm)	Concentration en ions chlorure (ppm)			
	200	1000	2000	15000
> 5000	1.4301			
2000 – 5000	1.4401 / 1.4362		1.4462	1.4507
1000 – 2000	1.4462		1.4507	
< 1000	1.4507			

Arcelor Mittal

Pumping station pipework, New York

One of 3 pumping stations using cast stainless steel laterals and wrought butterfly valves

Valves must operate when needed!

1.07 m stainless steel valve

Reducing Leakage, Trenchless Techniques and Plumbing

Couplings and clamps

Stainless steel is widely used for couplings, tapping sleeves, spacers and restraining and repair clamps

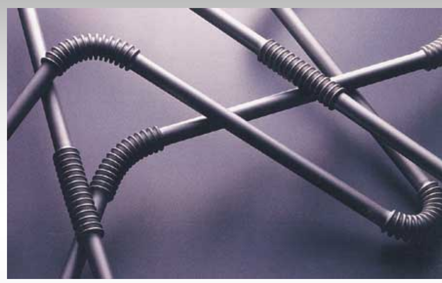
Tunnel lining

Stainless steel waterproof membrane in tunnel lining, Rovereto, Italy

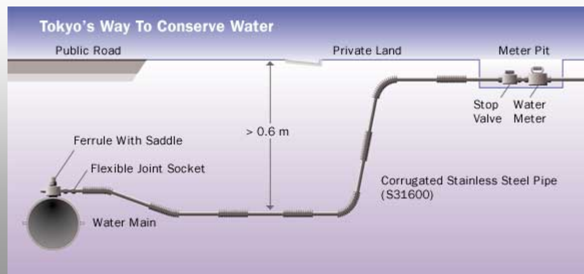
Reservoir lining

Stainless steel wallpaper lining of reservoir, Remscheid, Germany

Service pipe replacement, Tokyo



- 10 year programme
- **Leak-free – avoided need for a new reservoir**
- Earthquake resistant
- Ease of installation and 30% cheaper



Reducing Leakage

- Repair – stainless steel clamps
- Replace – strength of duplex may be advantage
- Reline – trenchless technology to avoid disruption

Padua, Italy

Trenchless technology minimises disruption

Push lengths up to 1 km

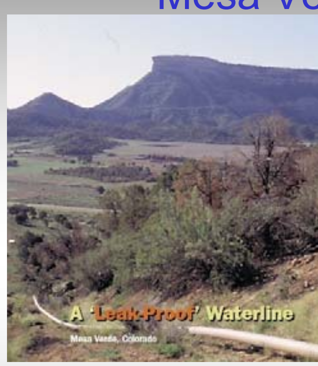
Costs for one example 40% of traditional full excavation

Nominated for European Sustainable Development Award in 2000

Trenchless technology

Pipe lengths are welded together in a small chamber then pushed inside the existing old main

Directional drilling to install water pipe through Mesa Verde National Park, USA



World Heritage Site

11 km of trenches unacceptable

Plumbing

- Growth continues in Germany – now ~15%
- Wide variety of fittings systems available
- Perception as an expensive option may be ignoring considerable time-saving during installation and more favourable costs for larger sizes.

Coiled stainless steel tubing for jointless hot or cold water supply in Japan

Mainly used in high-rise residential unit projects

Type 316 is used because it work hardens less than Type 304 , making it easier to bend

Standard sizes:

OD mm	Wall mm
9.52	0.7
12.7	0.8
15.88	0.8

Nisshin Steel Co Ltd

Plumbing

Pressfit system for joining stainless steel pipes

Using bronze pressfittings

Viega GmbH & Co

Munich stadium

Stainless steel pipe and fittings, China

Japanese compression fitting which shows if the joint has been tightened

The red ring disappears when the fitting is tight

Designed to avoid problems experienced with pressfittings that were not crimped and which leaked in wall cavities

Water tank, Bangkok

Refurbishment of New York Plaza Hotel

Lightweight, grade 316

Stainless steel pressure piping for high rise buildings

The Aurora residential tower

Brisbane, Australia

69 levels

Completed May 2006

$250 million development

Australian Stainless Steel Development Association

The Aurora residential tower – 69 levels

108 mm OD x 2 mm wall Type 316 stainless steel

Pressfittings

Working pressure: up to 2600 kPa or 26 Bar

System can be pressure tested up to 4000 kPa or 40 Bar

Australian Stainless Steel Development Association

Plumbing

Domestic hot water tank: usually 2304 duplex or 316L

Plumbing

Stainless steel tap, Italy

Durability, Life Cycle Cost and Recyclability

After 25 years!

Lightweight installation

Thin wall + high ductility → cheaper joining methods

Lightweight installation

Lightweight:

→ cheaper transport

→ more shop fabrication

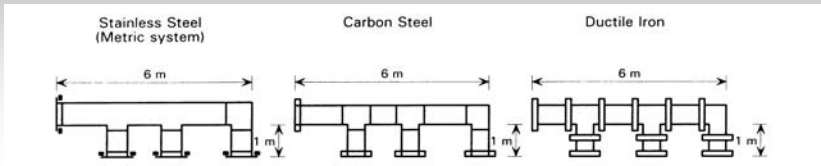
→ cheaper support systems

→ cheaper installation

350 mm drinking water main in a sports stadium, Detroit, USA

Comparison of Initial Costs

Example taken from:
The Steel Construction Institute, UK IGN 4-25-02, January 1999
Applications for Stainless Steel in the Water Industry



	DN150 6"NB		DN300 12"NB	
	Cost	Weight	Cost	Weight
Stainless steel	100	100	100	100
Carbon steel	208	346	234	395
Ductile iron	144	428	157	384
Saving over carbon steel	52%	71%	57%	75%
Saving over ductile iron	31%	77%	36%	74%

Cost Benefits of Using Stainless Steel

Costs over the life of the structure

- Smooth internal surfaces mean less energy for pumping
- Reduced inspection frequency and costs
- Reduced maintenance costs – no recoating
- Replacement is largely eliminated
- Reduced downtime
- Reduced leakage
- Long service life
- 100% recyclable at end of life

Life Cycle Cost =

(whole of life cost)

Initial Installed Costs

• Materials	• Fabrication	• Installation

+

Costs over the life of the structure

• Maintenance	• Replacement	• Disruption

Comparisons of Life Cycle Costs

Examples taken from:
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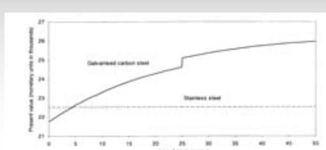
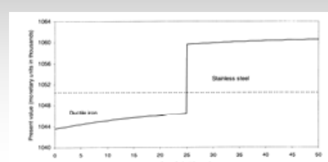
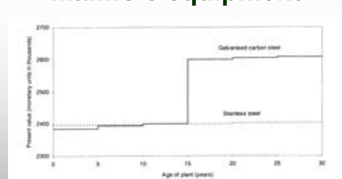


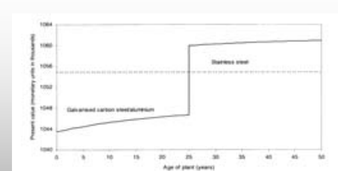
Manhole equipment



Pipeline equipment



Ductwork in sewage inlet



Elevated tank equipment

Life Cycle Cost Example

- First stainless steel raw water pipe in India
- 300 mm x 3 mm replaced 13 mm cast iron
- Lightweight meant easy installation in hilly country
- >50 year life expected (2 replacements of cast iron in that time)
- **Smooth bore meant sustained low pumping costs**
- **LCC analysis: 60% saving over 50 years**

Life Cycle Cost Example

Lightweight bridges are used to carry potable water and pedestrians across river spans up to 632 m in Japan

85% Type 304
10% Type 316
Some 2205 near the coast

No repainting

40% cheaper over 30 years

First one built: 1983

Max pipe diameter: 0.8 m

Max weight of stainless steel: 45 tons

There are now ~3000 such bridges in Japan (10,000 tons of stainless steel)

Aerial sewer pipe carrying sewage from a housing estate in Auckland, New Zealand

60 m long, 300 mm dia x 3 mm wall spiral welded 316L pipe with flanges in 304L.

It was lowered into place by helicopter.

Waste water treatment - LCC

← Old

Huddersfield, UK

Waste water treatment

New ↓

- 98% reduction in maintenance costs
- 25% extra plant capacity

Stainless steel is fully recyclable

- Stainless steel melted today contains about 60% recycled material
- The growth in the use of stainless steel prevents that percentage from being higher

Further information, guidelines etc

- I D Inox – www.idinox.com
- Nickel Institute – www.stainlesswater.org

A shining example after 25 years!