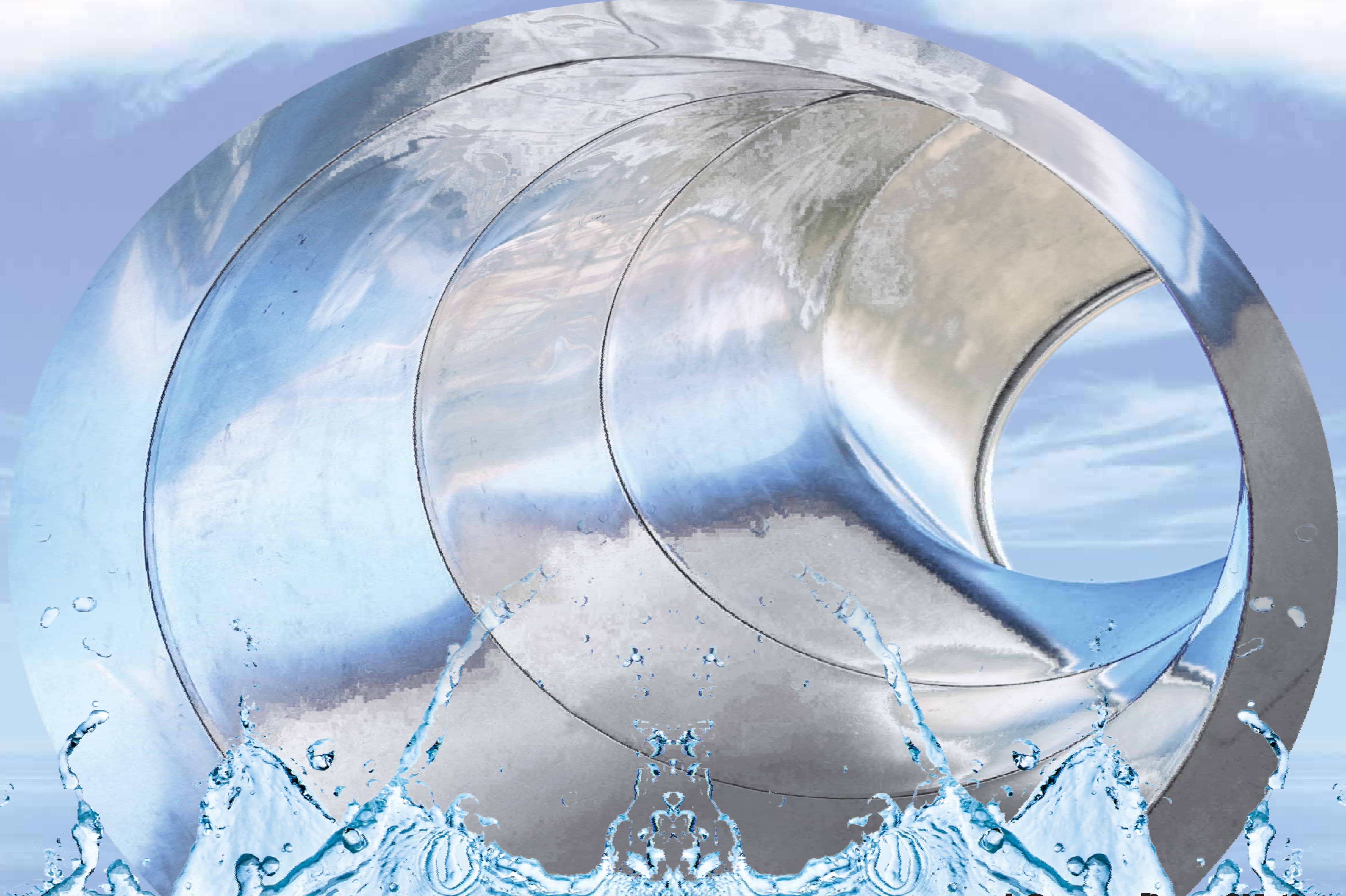
ISSDA STAINLESS STEEL

Stainless Steel for Water Service Pipelines, Treatment and Storage 2017

SAVE WATER,

BEFORE ITS TOO LATE !!

USE STAINLESS STEEL



A Compendium of National and International Articles

Disclaimer

Stainless Steel for Water Service Pipelines, Treatment and Storage

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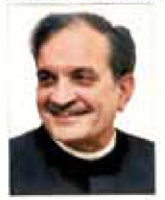
BIRENDER SINGH



सत्यमेव जयते

इस्पात मंत्री
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उद्योग भवन,
नई दिल्ली-110001
MINISTER OF STEEL
GOVERNMENT OF INDIA
UDYOG BHAWAN,
NEW DELHI-110001

Message

I am happy to learn that Indian Stainless-Steel Development Association is organizing a Seminar on Stainless Steel for Water Service Pipelines, Treatment and Storage.

Water is a national economic, environmental and social imperative. The loss of precious drinking water through pipeline leakages due to corrosion, not only causes deficit at the consumer level, but leads to immense economic wastages. Besides, poor water management in the supply chain can cause serious water-borne diseases. Therefore, there is the need to harness the best practices in water management to preserve and optimize this scarce resource.

With the corrosion resistance and hygiene friendly characteristics of stainless steel, I am hopeful that this metal can be used extensively to offer sustainable solutions in supply and storage of water. I urge participants and readers to keep the larger common good at the center of their deliberations.

I wish the organizers and participants all success in preserving the elixir of life better than has been done before.

(Birender Singh)

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विष्णु देव साय
VISHNU DEO SAI

No. 57/MRS/Steel/2017

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उद्योग भवन, नई दिल्ली-110011
MINISTER OF STATE FOR STEEL
GOVERNMENT OF INDIA
UDYOG BHAWAN, NEW DELHI-110011

MESSAGE

I am delighted to know that a seminar on Stainless Steel for Water Service Pipelines, Treatment and Storage is being organized by Indian Stainless-Steel Development Association.

The Indian stainless steel industry has been witnessing steady growth in the recent years. Today, India is the second largest producer of stainless steel products. Not only has the stainless steel industry grown in size, but also in its expanse and applications across different segments of the society. The inherent advantages of stainless steel, particularly in corrosion resistance, lower lifecycle costs and hygiene, make this metal a natural choice for usage in water management.

We are living in a water stressed environment where a large section of population still waits for clean and reliable drinking water supply. By plugging gaps in leakages and cleanliness standards, stainless steel can prove to be a game changer in the water management systems of India.

I wish this seminar all success, and I look forward to receiving actionable solutions from the organizers and participants.

(Vishnu Deo Sai)

Place: New Delhi
Date :

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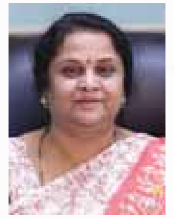
डॉ. अरुणा शर्मा, भा.प्र.से.
Dr. Aruna Sharma, I.A.S.



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17th October, 2017

MESSAGE

The Ministry of Steel has taken several initiatives for growth and development of the Indian steel industry, including the stainless-steel industry. The seminar on Stainless Steel for Water Service Pipelines, Treatment and Storage is one such initiative that strikes two goals at once: it provides sustainable solutions to water woes in the country, and promotes usage and application of a metal that is perfectly suited for the water industry.

We are aware that large parts of rural and semi-rural India still don't have access to clean drinking water. Even the urban areas face water shortage, which is further aggravated by leakage of precious potable water due to corroded pipelines. Stainless steel provides a sustainable solution to entire water management cycle with its properties of corrosion resistance and low maintenance. Cities like Tokyo and Seoul, which replaced its water service pipelines with stainless steel, have witnessed tremendous benefits in preventing loss of water, improving quality of water, and reducing maintenance costs.

As India modernizes and more smart cities come into being, it is time we adopt best practices in our systems of water management. This seminar provides a good opportunity for Urban Development & Municipal Authorities to interact with the stainless-steel industry and find resource-optimizing solutions for the people and the country.

(Dr. Aruna Sharma)

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ISSDA STAINLESS STEEL

Message

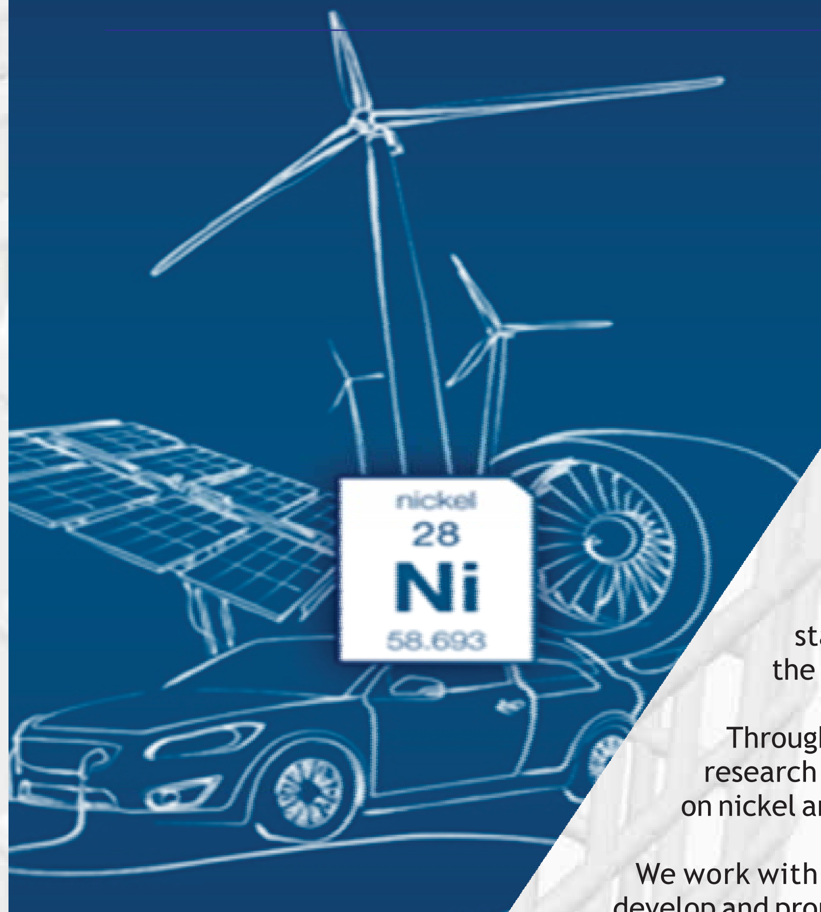
Indian Stainless Steel Development Association has been working towards finding stainless steel based solutions in different sectors like Architecture & Buildings, Transport and Process Industries. Our effort are also focused now on utilizing the sterling qualities of stainless steel to contribute towards more efficient water management solutions in the country.

While we are in a water stressed environment now, where large section of population still waits for clean drinking water, precious potable water is lost due to corroded distribution pipelines. This is adding huge economic and social cost to the limited water resources.

Stainless service pipelines adopted elsewhere in the world have given cost effective water management solutions through lower maintenance and water conservation, besides maintaining quality of potable water.

Indian stainless industry has now matured and grown to second largest in the world. We can now work with all stakeholders to provide sustainable stainless steel based water management solutions and share best global practices. This seminar is just beginning of our mission on offering stainless steel towards better water management.

K K Pahuja
President - ISSDA
2nd November, 2017



About Nickel Institute

Nickel INSTITUTE
knowledge for a brighter future

Nickel Institute is the global association of leading primary nickel producers. Our mission is to promote and support the use of nickel in appropriate applications. NI grows and supports markets for new and existing nickel applications including stainless steel; and promotes sound science, risk management, and socio-economic benefit as the basis for public policy and regulation.

Through our science division NiPERAInc. (www.nipera.org), we also undertake leading edge scientific research relevant to human health and the environment. NI is the centre of excellence for information on nickel and nickel-containing materials and has offices in Asia, Europe and North America.

We work with other international metals associations and stainless steel development associations to develop and promote the safe use of nickel around the world

We pursue market development through a worldwide network of highly qualified specialists.

We share our knowledge, offering free technical knowledge about nickel, its properties and uses to ensure optimum performance, safe handling and use.

We do promote the long term use of nickel to contribute to a sustainable future.

About Indian Stainless Steel Development Association (ISSDA)

The Indian Stainless Steel Development Association (ISSDA) is the unifying point for the growth and development of stainless steel usage in India. Founded in 1989 by leading stainless steel producers, it was formed with the explicit objective of diversifying the applications of stainless steel in India and increasing usage volumes in the country. At the point of formation of ISSDA, the main visible application in daily life was essentially household kitchenware. It currently has a membership of about 160 companies engaged in the stainless steel business.

Through the focused efforts of ISSDA and its member companies, the widespread and visible use of stainless steel in different walks of life is all too evident, especially in the Architecture, Building & Construction (ABC) and the Automotive, Railway and Transportation (ART) sectors. All-stainless steel railway coaches, Delhi Metro coaches, wagons for carrying coal & minerals, airports, corporate buildings, retail shops & shopping malls, the ever-wider use by the hospitality industry, even bus stands, railway platform roofs, building hardware - you name it and stainless steel is making its presence felt there. It has become the most aspired material of construction for thousands of small and big things, apart from the chemical and food process industry where the use of stainless steel is mandatory. With the economy booming, there is increasing demand for a wider range of products and services in stainless steel.

Such a change of fortunes for this material has been made possible through unremitting creation of awareness about the benefits of stainless steel amongst engineers, architects, designers, railway men, government bodies and a host of professionals responsible for specification of materials of construction and at the same time providing help to fabricators to fabricate and finish stainless steels in technically correct manner. Stainless steel production in India has increased from 0.5 million tonnes in 1994-95 to 3.34 million tonnes in 2016-17.

We firmly believe that in the ABC and ART sectors, we have only initiated the curiosity for stainless steel. There are several hundred cities looking forward for this aspirational product to reach them.

Newer sectors like household plumbing in thin-walled stainless steel and the water industry as a whole (potable water treatment, waste water treatment plants, large-dia pipes for carrying water), reinforcement bar for concrete, automobile exhausts for two & four wheelers and commercial vehicles, bus bodies etc., wait to be explored and exploited seriously.

Our website www.stainlessindia.org is an important tool for easy availability of information on stainless steel to the users.

The various activities to increase market opportunity for stainless steel are given as under:

Stainless India

Stainless India magazine highlights and catalogues applications of stainless steel in India and is published quarterly. Anybody interested in the applications of stainless steels can write to ISSDA for a free copy of the magazine.

Free Technical Services

ISSDA has access to vast technical resources in the selection of proper grade of stainless steel for various service environments, as well as matters related to fabrication. This service is provided free of charge. Similarly up-to-date information on material selection of stainless steel for various industrial service environments and fabrication is available in the form of technical publications. Technical queries and matters relating to sourcing of stainless steel products & services are answered free of charge.

Programmes

ISSDA organizes workshops for specific end-use applications of stainless steel targeted at designers, material specifiers, engineers, architects, maintenance personnel; workshops for improving the quality of welding & fabrication; international conferences for increasing the awareness of applications in the stainless steel industry.

Affiliations

ISSDA has close relations with the Nickel Institute (NI), stainless steel development associations (SSDAs) in other countries, the International Stainless Steel Forum (ISSF), the International Chromium Development Association (ICDA) and the International Molybdenum Association (IMOA). This helps ISSDA to learn from their experience to introduce stainless steel for new applications. ISSDA is a member of ISSF which is the apex body for coordinating world-wide market development activities and other interests of stainless steel producers and SSDA's around the world.

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WATER INDUSTRY
AND
STAINLESS STEEL - AN OVERVIEW

WATER
DEMAND AND SUPPLY : CHALLANGES IN INDIA

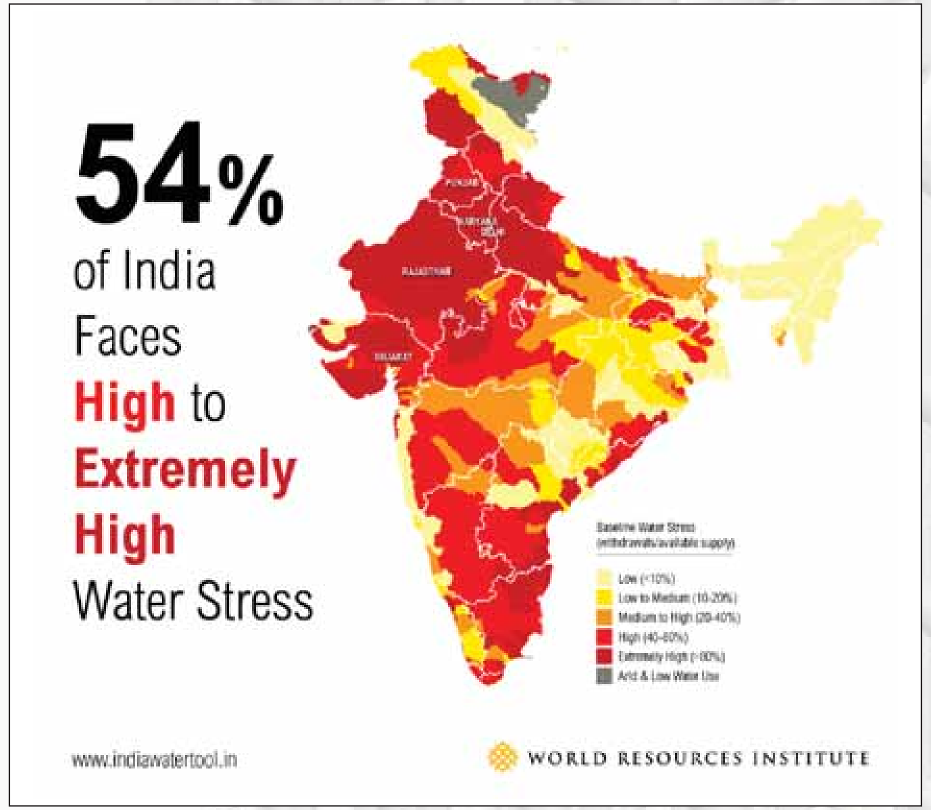
Water Demand and Supply: Challenges in India

India is moving towards greater water stressed environment where the water sources are depleting while the demand for clean and safe water is rising. Millions of Indians still lack access to clean drinking water, and the situation is only getting worse. India's demand for water, even after sustained efforts made in last 70 years. India currently has the world's second largest population, which is expected to overtake China's by 2050 when it reaches a staggering 1.6 billion, putting increasing strain on water resources. It is important to appreciate the fact that only 3 per cent of the world's water is fresh and roughly one-third of it is inaccessible. The rest is very unevenly distributed and the available supplies are increasingly contaminated with wastes and pollution from industry, agriculture and households.

With increasing industrialization and urbanization, more than 40% of India's available surface water is being used every year. In the NorthWesternregion, the breadbasket of India, about 80% of the surface water is being used.

According to a new report by the World Resources Institute it states that with more than half of India's total area is facing high to extremely high stress, almost 600 million people are at higher risk of surface-water supply disruptions.While the current situation looks quite grim, there is a possibility that it can get worse. Water supply is expected to fall 50% below demand by 2030.With 54 percent of India's total area facing high to extremely high stress, almost 600 million people are at higher risk of surface-water supply disruptions (figure below)

A rapidly growing economy and a large agricultural sector stretch India's supply of water even thinner. Meanwhile, India's supply of water is rapidly dwindling due primarily to over exploitation of water resources, although over-pumping and pollution are also significant contributors. Climate change is expected to exacerbate the problem by causing erratic and unpredictable weather, which could drastically diminish the supply of water coming from rainfall and glaciers. As demand for drinkable water starts to outstrip supply by increasing amounts in coming years, India will face a slew of subsequent



problems, such as food shortages, intrastate, and even international conflict.

Water scarcity involveswater *stress*, *water shortage* or *deficits*, and *water crisis*. This may be due to both natural and human factors. But, many reports suggest that the scarcity is contributed significantly by the human factors

Over the years, increasing population, growing industrialization, expanding agriculture and rising standards of living have pushed up the demand for water. Efforts have been made to collect water by building

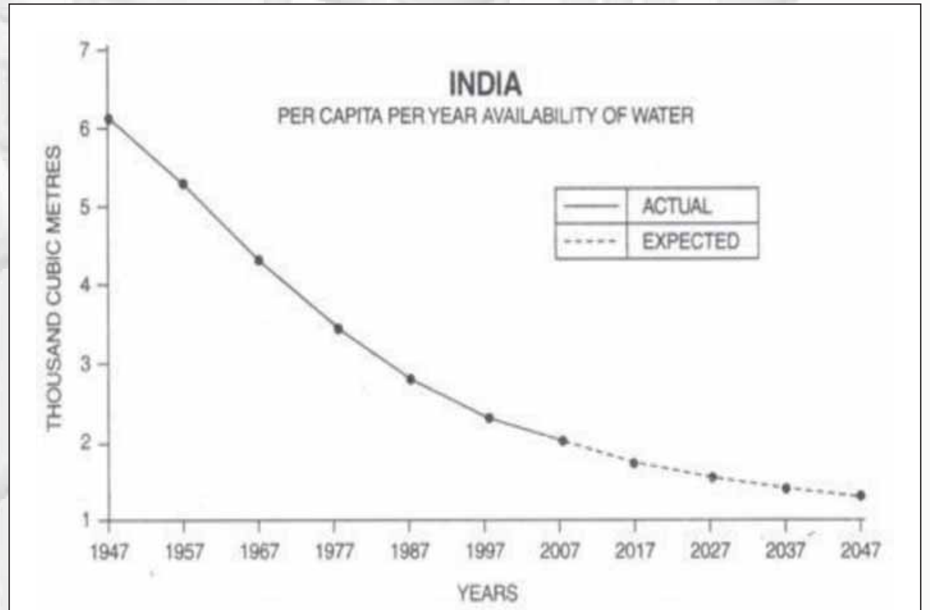


FIG. 16.6. India : Declining availability of water

dams and reservoirs and creating ground water structures such as wells. Recycling and desalination of water are other options but cost involved is very high.

However, there is a growing realization that there are limits to 'finding more water' and in the long run, we need to know the amount of water we can reasonably expect to tap and also learn to use it more efficiently.

In one of the most comprehensive report submitted by the Working Group on Urban and Industrial Water Supply and Sanitation for the Twelfth Five-YearPlan (2012-2017) it was stated that the quantum of water that is supplied is not the problem; the problem is its management and equal supply to all. In most cities, water supply is sourced from long distances. In this system of bringing water from far and in distributing it within the city, the length of the pipeline increases, as does the cost of infrastructure and its maintenance. In the current water supply system, there are enormous inefficiencies—losses in the distribution system because of leakages and bad management.

The quantum of water that is lost in distribution is a serious problem; This must be the focus of future policy and plans in cities. Currently, cities estimate that as much as 40-50 per cent of the water is 'lost' in the distribution system. Even this is a guesstimate, as most cities do not have real audits for the water that is actually supplied to consumers. Nagpur has prepared a water-loss balance sheet (table below). According to a calculation, of the 765 mld the city sources from the Pench forest and tiger reserve - some 40 kms away - it finally collects money for a mere 200 mld - or 32 per cent of what is sourced. The city loses as much as 140 mld, a quarter, in bringing water from the reserve. The revenue loss because of this leakage wipes out its entire budget. This is the scenario in all cities of the country.

Nagpur's water highway : losing as it travels

Nagpur	Losses	% Loss	Balance
Journey begins : Water is sourced	-	-	765 mld
Losses in canal	140 mld	18.3	625 mld
Measurement losses in raw water purchase	125 mld	16.3	500 mld
Treatment	20 mld	2.6	480 mld
Distribution / Commercial losses in theft/meter error	235 mld	32.6	245 mld
Collection losses	45 mld	5.8	200 mld

Source : S SHastak, 24X7 water supply project Nagpur, NESL, presentation made to Ministry of Urban Development, New Delhi, April, mimeo

The report also cited that the length of the pipeline adds to distribution losses and financial costs. This cost is not computed or understood when cities map out the current and future water scenario. In most cases (as evident from the city development plans submitted to JNNURM for funding), cities emphasize the need to augment supply, without estimating what it will cost, in physical and financial terms. Data suggests that most cities spend anywhere between 30-50 per cent of their water supply accounts for electricity to pump water. As the distance increases, the cost of building and then maintaining the water pipeline and its distribution network as increases. Worse, if the network is not maintained then water losses also increase. All this means that there is less to supply and more to pay. The end result is that the cost of water increases and the state is not able to subsidize the supply of water to all. The situation is worse in the case of the poor who often have to spend a great deal of time money to obtain water since they do not have house connections. Worse, as the city municipal water system collapses under the weight of under-recoveries, the rich move to private water sources like bottled water. The poor suffer the cost of poor health.

System input volume	Authorized Consumption	Billed authorized Consumption	Billed metered consumption	Revenue Water
			Billed unmetered consumption	
		Unbilled authorized Consumption	Unbilled metered consumption	Non –Revenue Water
			Unbilled unmetered consumption	
	Water Losses	Apparent Losses	Unauthorized Consumption	
			Metering inaccuracies & data handling errors	
		Real Losses	Leakage on transmission & Distribution main	
			Leakage & overflow at utility storage tanks	
			Leakage on service connections up to point of customer metering	

Table : International Water Association (IWA) Water Balance

In another study done and published in a paper "Non-Revenue Water Reduction Strategy in Urban Water System in India" the water balance study was done using the water audit software v4.2 developed by International water association to quantify the magnitude of Non-Revenue water which includes real losses, apparent losses, unbilled authorize consumption of the city Nagpur. Table below illustrates the components of water balance. The water balance for Nagpur city and all ten zones was developed.

The same study reported that Non revenue water for Nagpur city by volume accounted for 49% which is almost half of the total input of the system. The situation is similar in many cities.

Today there is a pressing need to find a solution to all the problems. Efficient delivery of water without any loss should be made primary objective of any authority dealing with supply of water. In the current scenario any loss of treated or uncontaminated water should be considered a national loss.

A recent press report states that Delhi loses over 45% of supplied water due to leakages (copy on next page).

While apparent losses constituting unauthorized consumption are drawing the attention of utilities by better metering and surveillance, it's the real loss due to leakages and poor maintenance which needs even greater attention. The distribution service pipeline, once laid, are seldom repaired or even inspected and leakage due to corrosion or poor maintenance account for almost 50% of NR Water, It is this aspect which can be addressed by shifting to stainless steel service pipelines. Cities like Tokyo, Seoul and Taipei decided to shift to stainless steel service pipelines almost 20 years back when faced with problem of leakage and high maintenance cost. The results have been significant water conservation and savings in separate costs. These case studies are included in the booklet for ready references.

ISSDA STAINLESS STEEL

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CM wants water audit, DJB to go for flow meters

Delhi Loses Over 45% Of Supplied Water Due To Leakages

Ambika.Pandit

Representational image

HUGE WASTE: CM Arvind Kejriwal was shocked to know that the capital loses so much water during transmission and distribution

New Delhi: To gather real-time data on loss of water in the distribution network, Delhi Jal Board plans to install flow meters on primary and secondary underground reservoirs. Concerned at the extensive water loss and the fact that no water audit has ever been carried out by DJB, chief minister Arvind Kejriwal asked the water board to put in place a mechanism for collection of data on water losses.

Delhi has an installed capacity for the supply of 903 million gallons a day, and while there are no definitive figures for water loss during transmission and distribution, it is estimated to be a bit over 45%. The CM sees this as a major concern in the water situation. After taking over as chairman of DJB in September, Kejriwal realised to his shock that a massive amount of water was lost due to leakage, theft and other reasons.

At a review on Friday, Kejriwal is learnt to have directed the installation of flow metres at the earliest. According to sources, DJB has told the CM that installation of permanent meters would take 6-10 months, so for now clamp meters would be installed to determine the causes of the water loss.

The matter was apparently also discussed at length in the quarterly review of the state government's outcome budget indicators and targets held in July-August.

DJB intends to begin the process with around 600 underground water reservoirs, which will require 2300 flow meters. However, the meters will be installed only temporarily at the underground reservoirs to collect data over a few days. On the basis of the findings, a plan to check water losses will be determined. To enable this assessment, DJB called for companies to bid for installing the flow meters, and at least seven parties have shown interest. The water board is also learnt to be working on installing permanent flow meters.

This is not the first attempt of DJB at a mechanism to track and record water losses. Kejriwal was apparently informed at the outcome budget review that earlier tenders for bulk supply of flow meters had failed to evoke response. According to DJB officials, a significant amount of distribution losses happen at the stage of the water reaching the household because the pipes at this point are often neglected and unrepaired. The flow meters, though planned at the underground reservoir stages, are expected to provide concrete indicators of where the most water losses occur, sources said.

The current system takes the city's water through 10 water treatment plants to 117 primary reservoirs and from there to 500 secondary reservoirs. It is from here that the water is supplied to consumers. The figure of 45-50% loss of supplied water is based on feedbacks and estimated capacities. The use of flow meters will make it possible to track the actual losses.

Reliable sources told **TOI** that DJB has informed the CM that in the last few weeks, its executives have discovered 3,000 instances of illegal tapping of its supply lines. "The possibility of more illegal tappings is high," a source said.

Source : Times of India, 21st October, 2017.

STAINLESS STEEL
A MATERIAL OF CHOICE

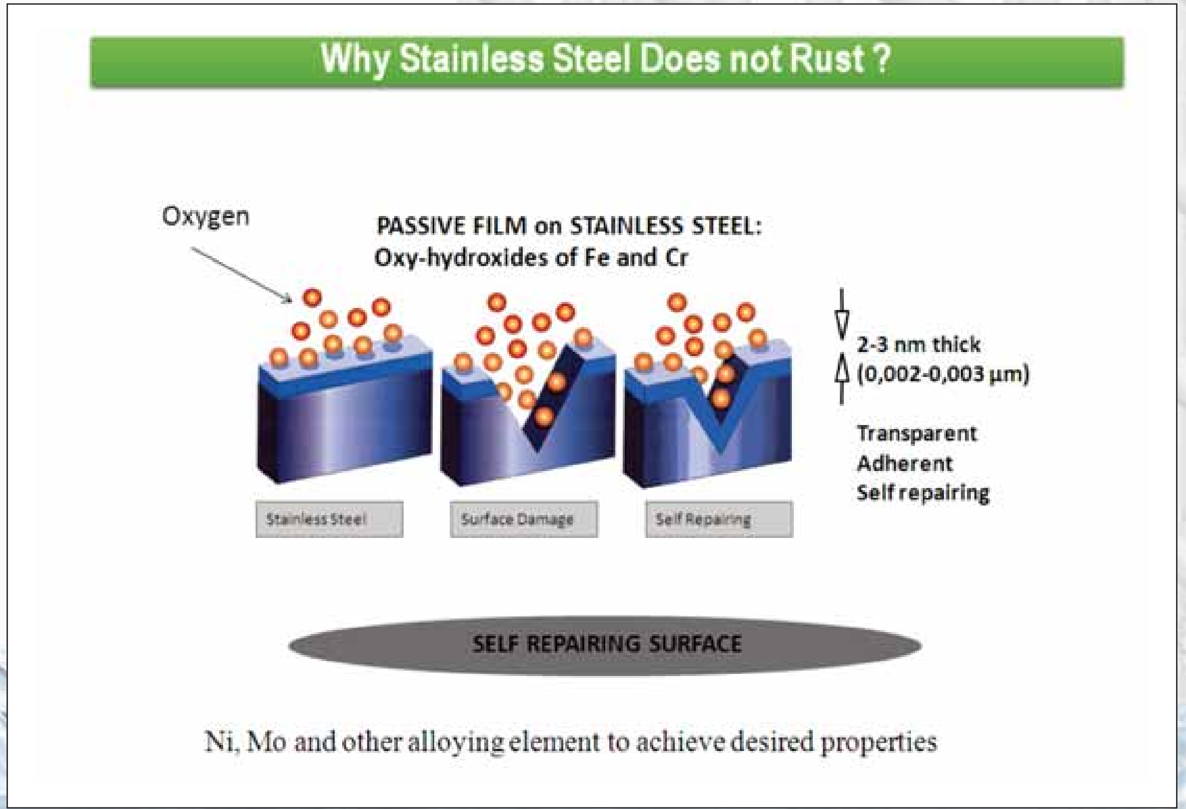
Stainless Steel
A Material of Choice

Stainless Steel is a wonderful hygienic and durable alloy. It has become a favorite and material of choice for the very same reasons. While working with other materials, common problems encountered are related to corrosion, oxidation, loss of Strength at high temperature, ductility, toughness, formability weldability, surface finish, etc. Stainless Steel is preferred whenever desired solutions are not found with other competing materials.

Stainless steel is the generic term used to represent the family of corrosion resistance alloys. This metal derives its name because it does not stain, rust or corrode, hence, named as "STAINLESS STEEL". Its properties are more enhanced with other elements such as Molybdenum, Nickel and nitrogen. With addition of these elements SS is produced in variety of grades for usage in range of industries as per their requirement.

One of the unique features of this metal, is that it can be reused and recycled, making it environment friendly. Over 50% of the new stainless steel is made from re-melted scrap-metal making it a **'Green Metal'**. Stainless Steel is also dubbed as **'Wonder Metal'** because of its many distinguished characteristic like low maintenance, weld ability, aesthetic appeal, dexterity, durability, low life cycle cost, good corrosion resistance to name a few. These qualities make it an ideal material for many applications for usage in various sectors. One can actually reflect, how from the start of our day till its end, Stainless Steel touches our lives in so many different ways!

The basic principle of using stainless steel comes from its ability to resists corrosion. The ability to resist corrosion comes by adding chromium to Iron. When a minimum 10.5 % Chromium is added to iron it becomes corrosion resistance. This resistance comes from the formation of an oxide layer of Chromium at the surface which does not allow iron in stainless steel to corrode. The formation of this layer is dynamic. In case you scratch or damage the surface then it takes oxygen from the atmosphere and reform the chromium oxide layer. This process is known as re-passivation. Therefore stainless steel remains protected all the time with the help of this passive layer. This also gives an opportunity to reduce the usage of paints for corrosion protection saving cost and environment. Please see the pictorial representation below.



Apart from corrosion resistance properties stainless steels have several other properties which makes it a preferred choice compared to other competing materials.

1. **Hygiene** The easy cleaning ability of stainless makes it the first choice for strict hygiene conditions, such as hospitals, kitchens, abattoirs and other food processing plants.
2. **Aesthetic appearance** The bright, easily maintained surface of stainless steel provides a modern and attractive appearance.
3. **Strength-to-weight advantage** The work-hardening property of austenitic grades, that results in a significant strengthening of the material from cold-working alone, and the high strength duplex grades, allow reduced material thickness over conventional grades, and therefore cost savings.
4. **Ease of fabrication** Stainless Steel can be cut, welded, formed, machined, and fabricated as readily as traditional steels.
5. **Impact resistance** The austenitic microstructure of the 300 series provides high toughness, from elevated temperatures to far below freezing, making these steels particularly suited to cryogenic applications.
6. **Long term value** When the total life cycle costs are considered, stainless is often the least expensive material option.
7. **Environmental compatibility** In use stainless steel is durable and requires a minimum of maintenance, outlasting many competing products and eliminating requirements for additional potentially hazardous materials such as paint, fire protective coatings, cleaners and solvents. Stainless steel is a valuable scrap material. It is 100% recyclable and a preferred raw material input by steel makers.

STAINLESS STEEL IN WATER SERVICE PIPELINES

A PERMANENT SOLUTION TO WATER LOSS: CORRUGATED STAINLESS STEEL SERVICE PIPES

A PERMANENT SOLUTION TO WATER LOSS:
CORRUGATED STAINLESS STEEL SERVICE PIPE

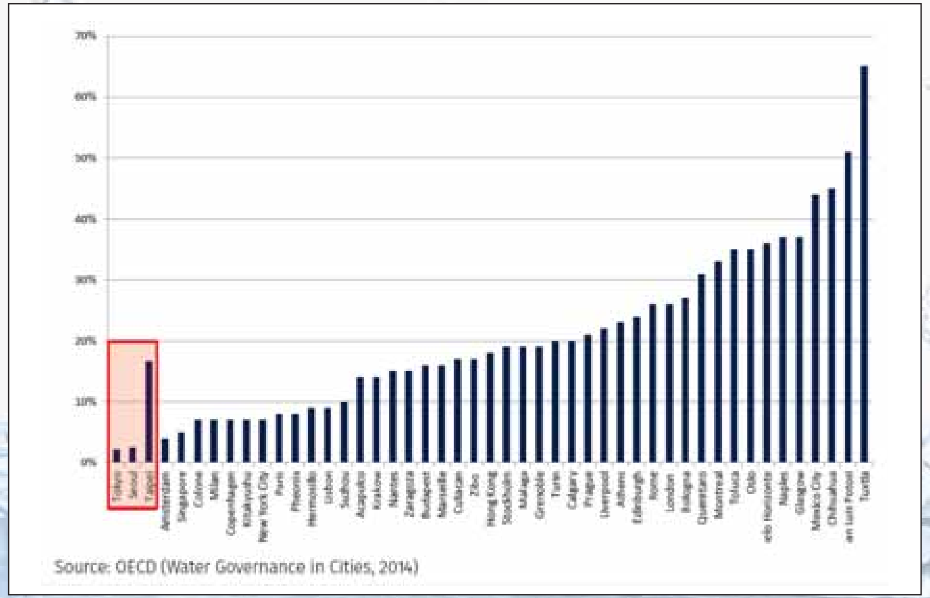
- Nicole Kinsman, IMOA - Richard Matheson, Nickel Institute - Gary Coates, Nickel Institute

INTRODUCTION

The costs due to leaks in distribution systems are not only the direct cost of the water that cannot be sold but they also consist of additional costs that are incurred as even more water must be found, treated and stored.

This problem affects rich and poor cities alike, as shown in the following chart. Many of the utilities in North America do not know exactly the extent of the water loss in their system.

Figure 1: Leakage rate in major cities.



Both Tokyo and Taipei have determined that some 95% of leakage repairs affect their service pipes of 50 mm (2 inch) diameter or less. Historically, service pipes there had been constructed of lead, iron or plastics.

Once a service line is in the ground various forces, such as:

- Vibrations from traffic and construction work
- Subsidence
- Seismic events

can cause the pipes to deform, become detached or even break.

The lead lines not only had leakage problems, but there were also grave health concerns which required accelerated replacement of these lines.

THE ANSWER

In 1980, to combat the scourge of leaks, Tokyo instituted a three part solution to the problem:

- Replace the existing service pipes with Type 316 (UNS S31600) stainless steel and the cast iron mains with ductile iron
- Improve leakage detection
- Improve response time when a leak is detected In 1998 corrugated Type 316 stainless steel pipe was introduced instead of straight pipe and fittings. The pipe is corrugated at regular intervals so it can be easily bent during installation to accommodate changes in direction without additional joints. It also allows the pipe to absorb he stresses from vibrations, subsidence and seismic events. The number of joints was significantly reduced by using a single length of corrugated pipe.

Figure 2: Corrugated 316L stainless steel pipe

Tokyo's success at reducing leakage attracted the attention of Taipei and Seoul. In 2003, Taipei began a similar program to Tokyo. The city went through a severe drought in 2002 which resulted in intermittent water supplies to its residents over a 49-day period. Of the 450 metering areas in the city, 40% were losing half or more of their water before it reached consumers.

Figure 3: Traditional vs flexible service line

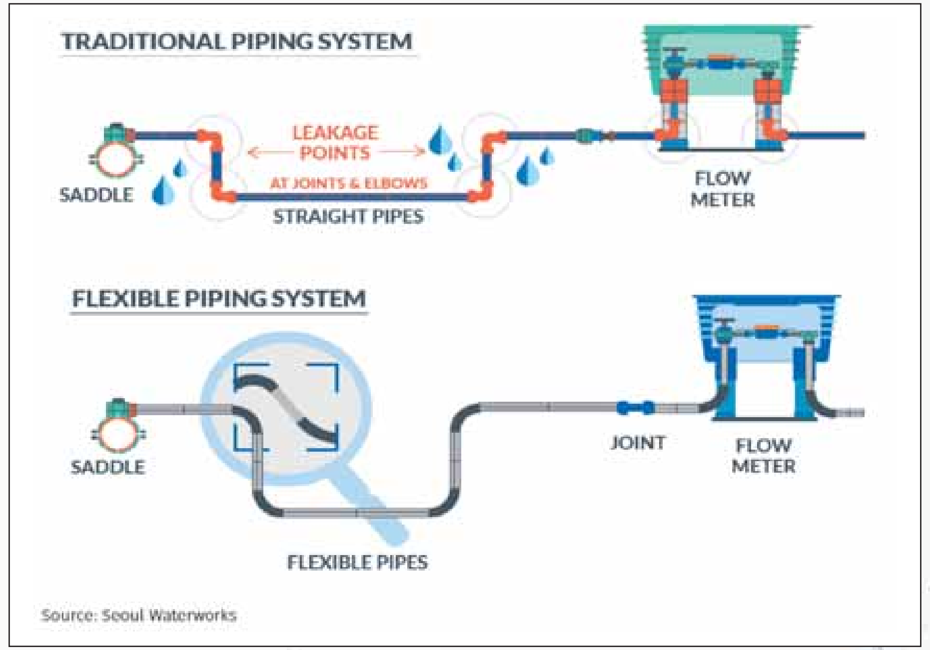
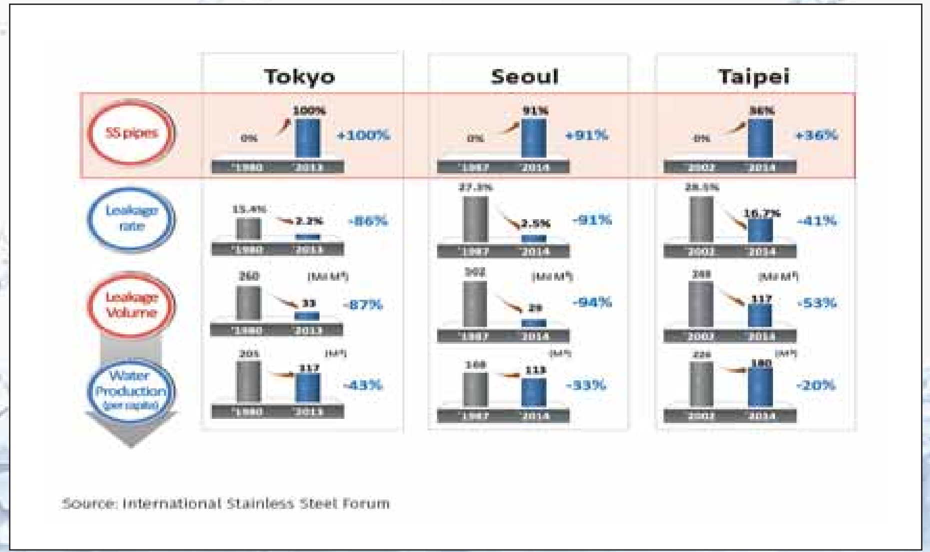


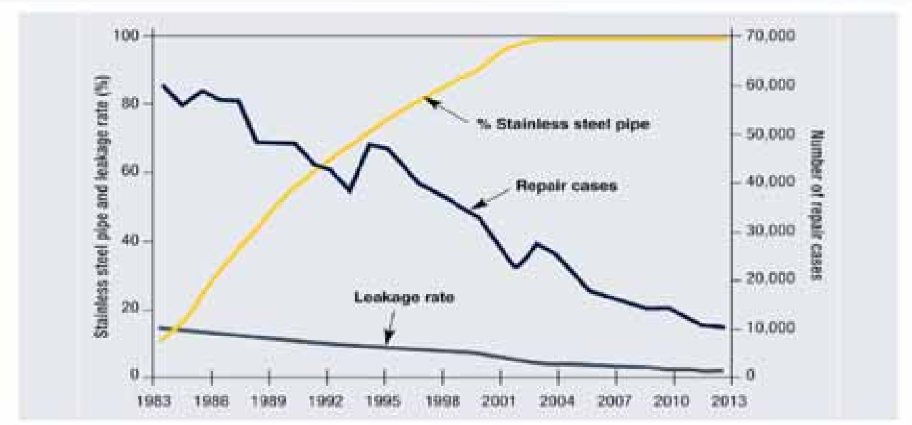
Figure 4: Results of projects in Tokyo, Seoul and Taipei



THE RESULTS

Since 1994 Tokyo has reduced annual water leakage by nearly 37.5 billion gallons, with savings in excess of US$200 million per year. Taipei's reduction since 2002 is about 38.6 billion gallons annually. More importantly, Taipei was able to provide continuous service in 2014 with water to spare, during a more severe drought than the one which instigated the project in 2002.

Figure 5: Correlation between repair cases, leakage rates and installation of stainless steel pipes in Tokyo.



Source: Tokyo Waterworks Bureau

WHY TYPE 316?

Type 316 stainless steel with 2% molybdenum and 10% nickel content has excellent corrosion resistance in a wide range of soils. Tokyo expects service life to be in excess of 100 years.

Table 1: Major elements in the composition of Type 316 - in weight-%

Cr	Ni	Mo	Mn	Si	Fe
16.2	10.1	2.1	1.2	0.5	bal

Type 316 stainless steel is essentially inert in potable water, with negligible leaching of alloying elements, and therefore does not affect the water.

ADVANTAGES

Stainless Steel Characteristics

- Corrosion resistant
- Durable
- Hygienic
- Strong
- Lower Life Cycle Cost
- Not susceptible to cracking
- Lower maintenance costs
- Improved water quality
- 100% recyclable

Flexible pipes

- Reduce leakage by minimizing the number of joints
- Improved workability
- Flexible and easy to install
- Resistant to seismic shocks and subsidence
- Matching fittings to connect to the water main and valves and meters

CONCLUSIONS

The corrosion resistance, durability, resilience and reduced number of joints of corrugated stainless steel service pipe has played an important role in stopping leaks.

The experience of Tokyo, Seoul and Taipei proves the suitability of stainless steel for service lines even for very large systems. While the initial cost compared to competing materials may be higher, stainless steel has been shown to be a good investment over its long life, paying back each year in reduced maintenance and cost per gallon processed.

SAVE WATER, SAVE LIFE

A WORKABLE, LASTING SOLUTION FOR WATER LOSSES THROUGH LEAKING WATER PIPES

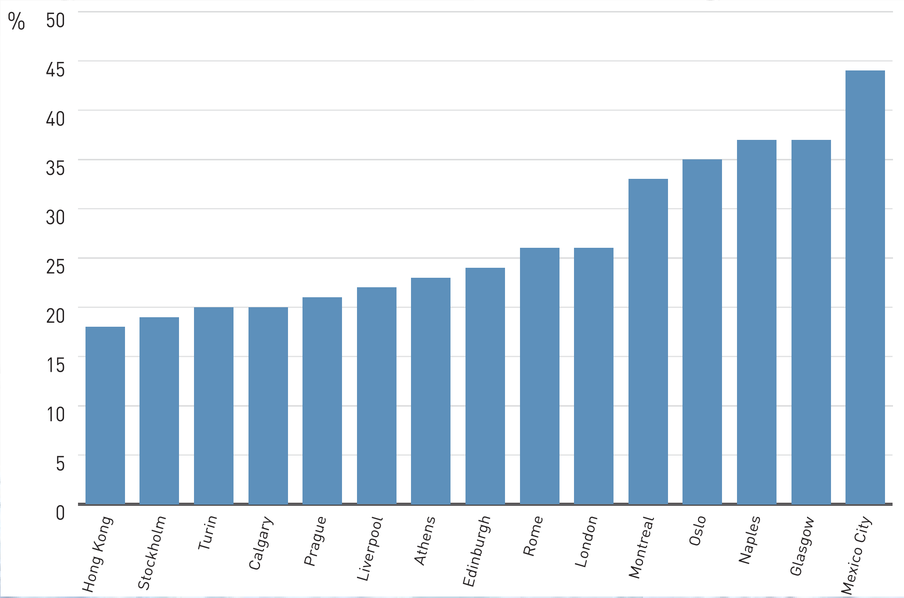
A Workable, Lasting Solution for

Water Losses through Leaking Water Pipes

By ISSF

Introduction

Water Loss through Leaking Water Pipes in a selection of Cities. Water loss through leaking water pipes is a problem for cities all over the world. Some of them are losing water at upwards 40% per year, and this is all water which has already been treated. A recent study by the OECD has shown that it is not on the under developed or even the developing cities that are so afflicted - even the capital cities of major economies are losing far more water than is sustainable or even viable, as the table on this page illustrates.



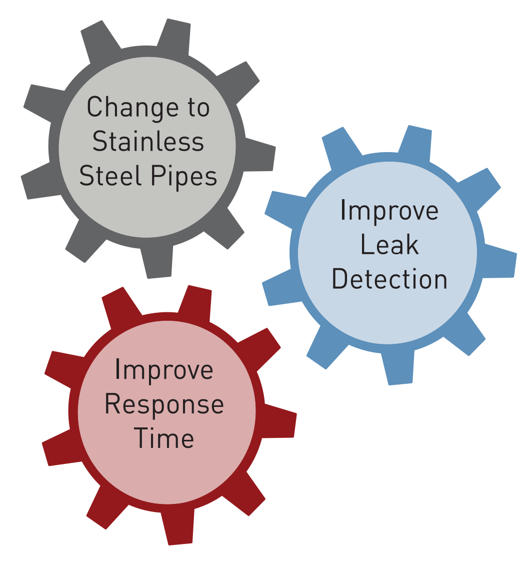
Leakage rate in major cities
Source: OECD (Water Governance in Cities, 2014)

Managing Leaking Pipes

Our studies have shown that the first, and most important step, is to replace the existing pipes with stainless steel pipes. This material has a higher strength to weight ratio, is easier to work with, is resistant to corrosion and is strong enough to with stand shocks, even as a result of seismic activity. It will therefore last longer between maintenance programs.

But even stainless steel is susceptible to leaks if severe damage occurs. It is therefore to introduce a secondary management system - improving the rate of detection of recurring leaks.

Last, but by no means least, there must be a rapid response team that works around the clock and is capable of reaching the site of detected leaks and repairing them quickly and effectively.



Each of these three points are critical to the final solution. No one of them, standing alone, will be sufficient.

Stainless Steel Water Pipes

Material Benefits

Stainless steel has high strength and is a very durable material. It is also less susceptible to cracking than competing materials. It is also corrosion resistant, thus obviating the need for painting or other protective layers.

Stainless steel is exceptionally wear resistant. It has a hard, smooth surface, making it more difficult for bacteria to adhere and grow, thus making it very hygienic. Stainless steel therefore plays a key role in the production, preparation and transport of food and drink for 100 years.

It is chemically inert, meaning that it does not react with the food or drinks with which it comes into contact. For the purpose of transporting water, the ideal solution is to use stainless steel as corrugated pipes. The introduction of corrugated pipes minimises the risk of leaks by reducing the number of welded joints that would otherwise be necessary.

A secondary benefit is that the corrugations make the pipes easier to bend on site, thus making bending in inaccessible places easier and reducing the numbers of welded joints. These pipes improve productivity and are also resistant to seismic shocks.

Environmental Benefits

Over its entire lifecycle, stainless steel has one of the lightest environmental impacts of all known engineering materials. At the end of its long life, it is capable of being 100% recycled to create new stainless that will be as strong and long-lasting as the original product.

Corrugated stainless steel pipes.
Source: Korea Water Works Association (kwwa.or.kr)

Life Cycle Costing

Stainless Steel has a higher initial investment cost than many of its competing materials. However, when viewed across the full extent of its projected useful life, and noting that it requires very little maintenance and repairs, it is a less expensive option.

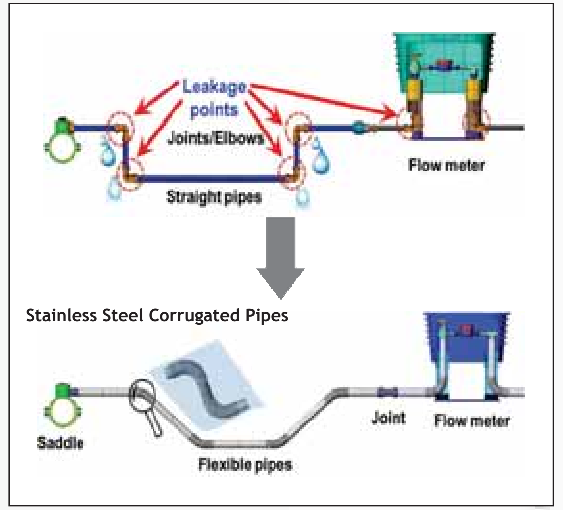
Assuming a useful life of 100 years at current real interest rates, the costs of using other materials total is higher by 400%.

	Life Cycle Cost
Stainless Steel	$1,932
PVC	$7,978
PE	$7,878

For 100 years service life

Stainless Steel Corrugated Water Pipes

Traditional Piping System



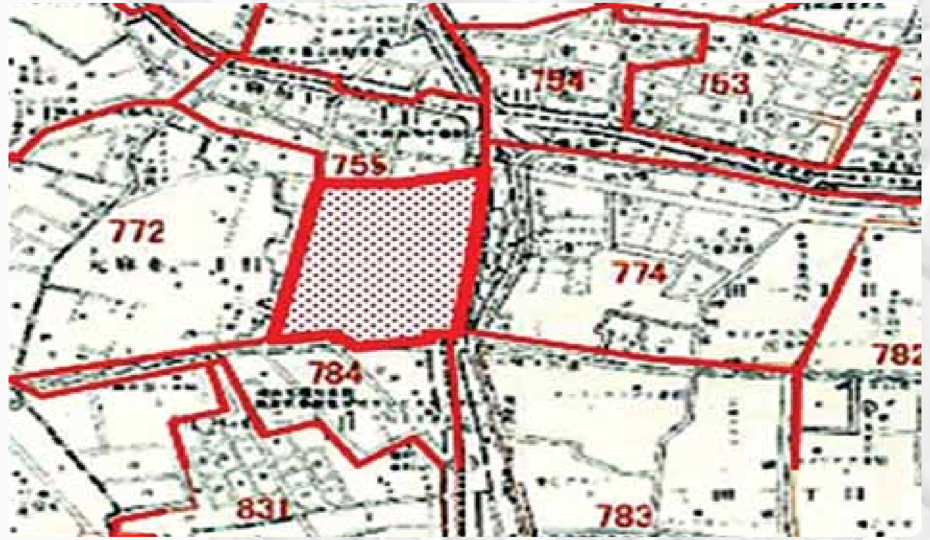
A flexible stainless steel corrugated piping system:

- Avoids leaking at joints
- Flexible pipes reduce the number of joints
- They can resist seismic shocks

Improving detection and repair

Planned detection

- A service area is divided into grid blocks
- Each block is investigated regularly for leaks



Example of how Tokyo is divided into grid blocks to plan the regular detection of leaks

Planned response

- There is an immediate response to reports of leaks
- Operating teams are ready 24/7 throughout the year

Repair works in Korea

Life Cycle Cost Analysis

The Eiffel Tower

The Eiffel Tower was built in 1889 for the Paris World's Fair. It was intended as a temporary structure, to be taken down after the Fair, but the city decided to retain it and today it is an iconic structure, which immediately identifies the city's silhouette.

The structure was built using 7,300 metric tons of carbon steel, with 18,000 separate parts and 2.5 million rivets. To maintain a secure covered surface of the steel and therefore avoid surface oxidation, the structure must be repainted in cycles of seven years. Each repainting takes 18 months and requires 25 painters, using 60 metric tons of paint, 1,500 sets of work clothes, 1,000 pairs of gloves and 2,000 square meters of protective netting. If this structure had been built using the appropriate grade of stainless steel it is reasonable to assume that the only maintenance cost would have been for the cleaning of the material every 30 years or so, using ordinary household cleaning materials. This is indicated by the "as-new" condition of the stainless steel roof on the Chrysler Building in New York, which has been in place for 87 years and has only been cleaned three times.

This example illustrates how, despite its higher initial cost, the longer useful life of stainless steel, can save money by reducing the cost of repairs, replacements and maintenance.

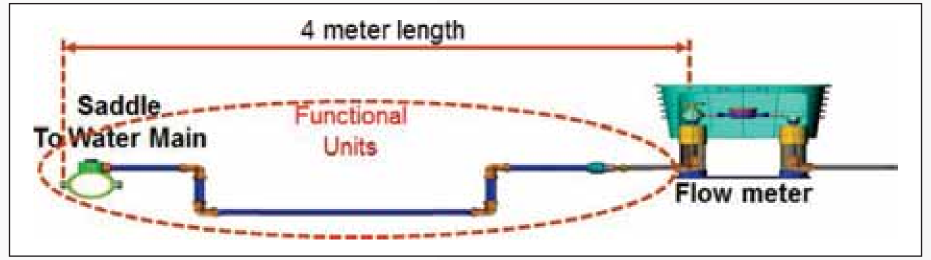
All Costs Are at Present Value

Total life cycle cost (LCC)		Initial materials acquisition costs (AC)		Initial materials installation & fabrication costs (IC)		Operating & maintenance costs (OC)		Lost production costs during down-time (LP)		Replacement materials costs (RC)
LCC	=	AC	+	IC	+	$\sum_{n=1}^{N} \frac{OC}{(1+i)^n}$	+	$\sum_{n=1}^{N} \frac{LP}{(1+i)^n}$	+	$\sum_{n=1}^{N} \frac{RC}{(1+i)^n}$

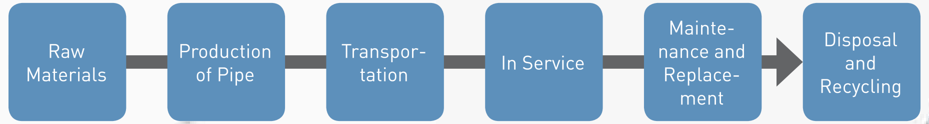
Where: N = Actual Service Life, i = Real interest rate, n = Year of the event

Definition of the System

4 meter lengths (20Ø) of service pipes with a service life of 100 years. Service pipes extend from the water mains to the household water meter and are inclusive of joints, elbow, T-joints and valves.



The LCC analysis was calculated from cradle to grave.



Assumptions	Stainless Steel (316)	PVC	PE
1. Service life	100 years	20 years[1]	20 years[1]
2. Real interest rate	0.27%[2]		
3. Initial material cost for a 4-meter corrugated pipe (including parts)	$297[3]	$89[3]	$67[3]
4. Initial installa-tion (incl. labour costs)[4]	$1,683 (assumed to be the same for each case)		
5. Operating and maintenance costs	Assumed to be zero (but maintenance and downtown costs exist in practice. Minimising that disruption is important)		
6. Lost production costs during down-time			
7. Replacement costs[4]	$1,980/100 years	$1,772/20 years	$1,750/20 years
8. Residual value (Recycled scrap)[5]	$100/100 years	$0	$0

1. Service life estimation from Seoul Waterworks
2. Real interest rate forecast from IHS Markit
3. Pipe cost taken from Incheon (South Korea) example
4. Replacement cost taken from Incheon (South Korea) example
5. Stainless steel is capable of 100% recycling

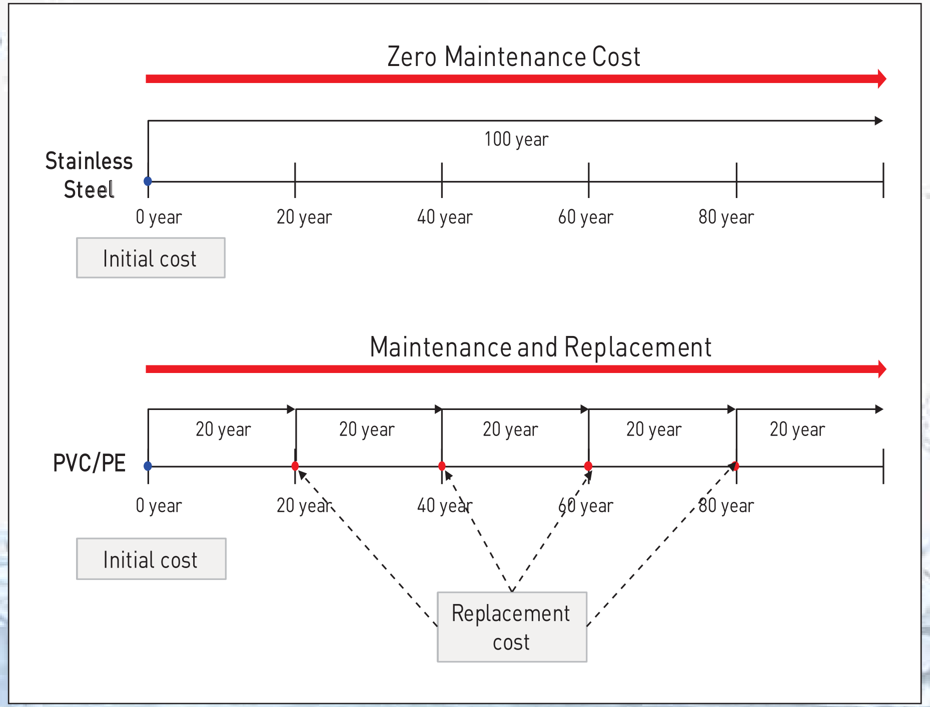
Cost diagram for each material

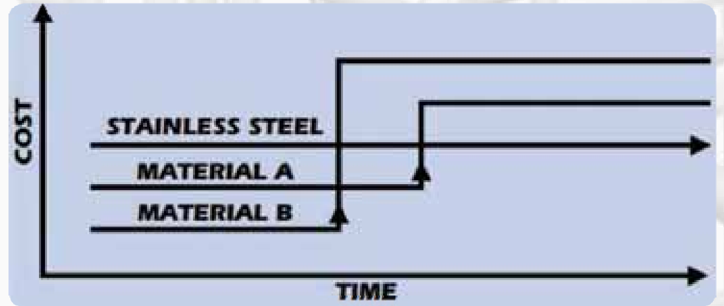
Duration	Stainless Steel	PVC	PE
100 years	1,932	7,978	7,878

The analysis of the Life Cycle Cost for grade 316 stainless steel illustrates that it is a less expensive product when viewed over its useful life.

Alternatives which were tested by the Tokyo Water Board are shown to have a shorter life cycle and therefore a higher cost.

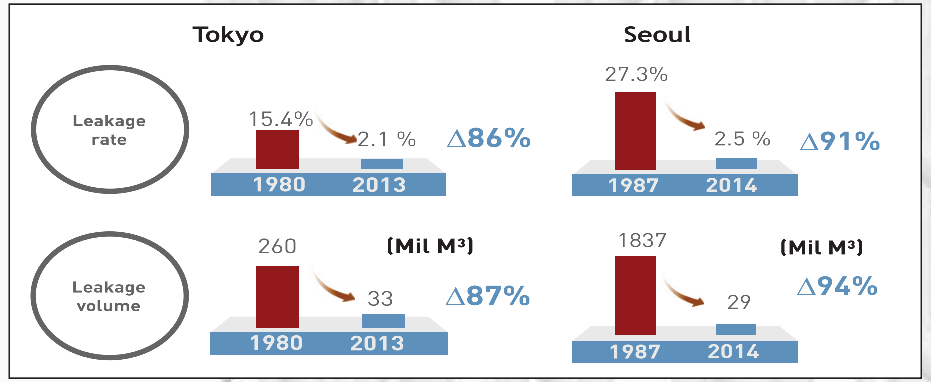
Our assumptions have been based on a life span of 100 years (although the Chrysler Building indicates 100 years is a conservative estimate) and on current interest rates.





Schematic representation showing the cost of alternate materials A and B substantially increases over time while the cost of stainless steel remains constant.

Results of the projects in Tokyo and Seoul



User Experiences

Tokyo Water Board

The material change to stainless steel was carried out based on a thorough examination and it turns out to be the right decision. We found there was a considerable effect in the stainless steel application on both leakage and water quality.

Okabe Takeshi, Manager of the Water Supply Division

Seoul Water Works

As we expected, stainless steel pipes have contributed to cleaner water quality and longer service life than other materials as well. The corrugated section contributed to an improved workability and a decrease in leakage.

Kim HyenTon, Director of the Water Distribution Department

Stainless Steel Water Pipes in Tokyo

Tokyo Water Works in Figures (2013)

- Service population: 13 million
- Annual distribution volume: 1,523 million m^3
- Leakage volume: 33 million m^3
- Water leakage rate: 2.2%

	1980	2013
Population (Mil)	11.6	13.3
Distributed volume (million m^3)	1,692	1,523
Leakage volume (million m^3)	260	33
Leakage rate (%)	15.4	2.2

Major Challenges

- Critical water shortages
- Leaking water pipes
- High chloride ion content in the soil
- Concerns about maintaining a good water quality
- Susceptible to severe seismic shocks
- Severe localised flooding around the area of leaks, even causing some roads to collapse

Why was 316 chosen over 304?

The Tokyo Water Board chose the higher alloyed grade 316 stainless steel for its improved corrosion resistance following extensive ground testing. They said that it was selected because they wanted the best available material. The cost of the material was less important than strength and durability because security of water supplies was the most important consideration.

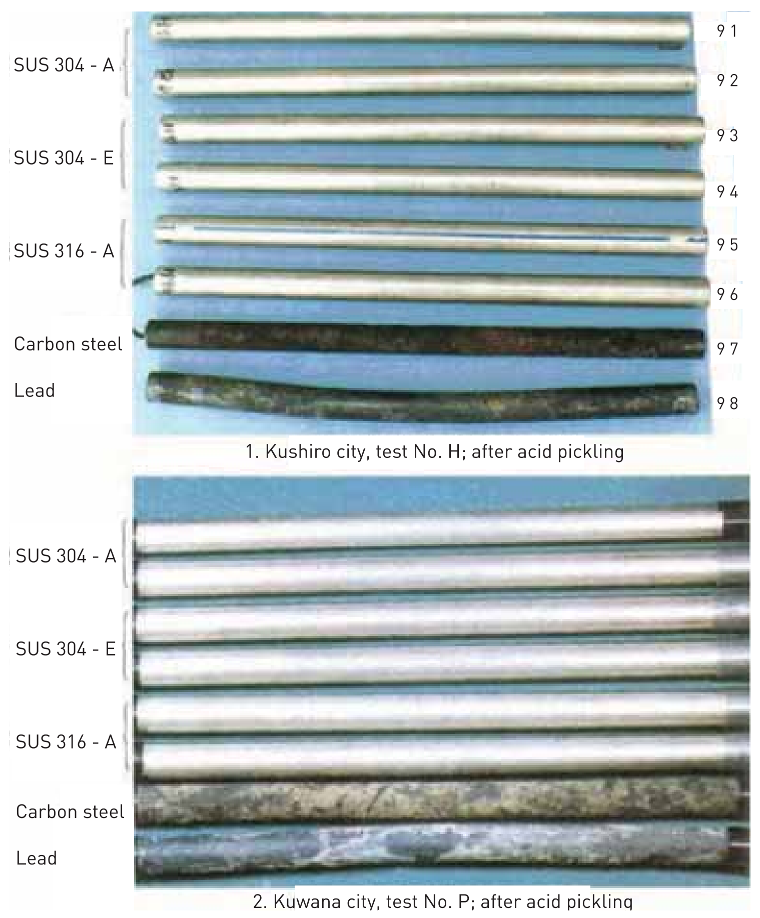
Underground burial tests

To check the corrosion behaviour of the pipes and to collect data on their corrosion resistance, the Tokyo Water Board commissioned tests using pipes made from a number of competing products, by burying them underground at 10 different sites, for a period of 10 years.

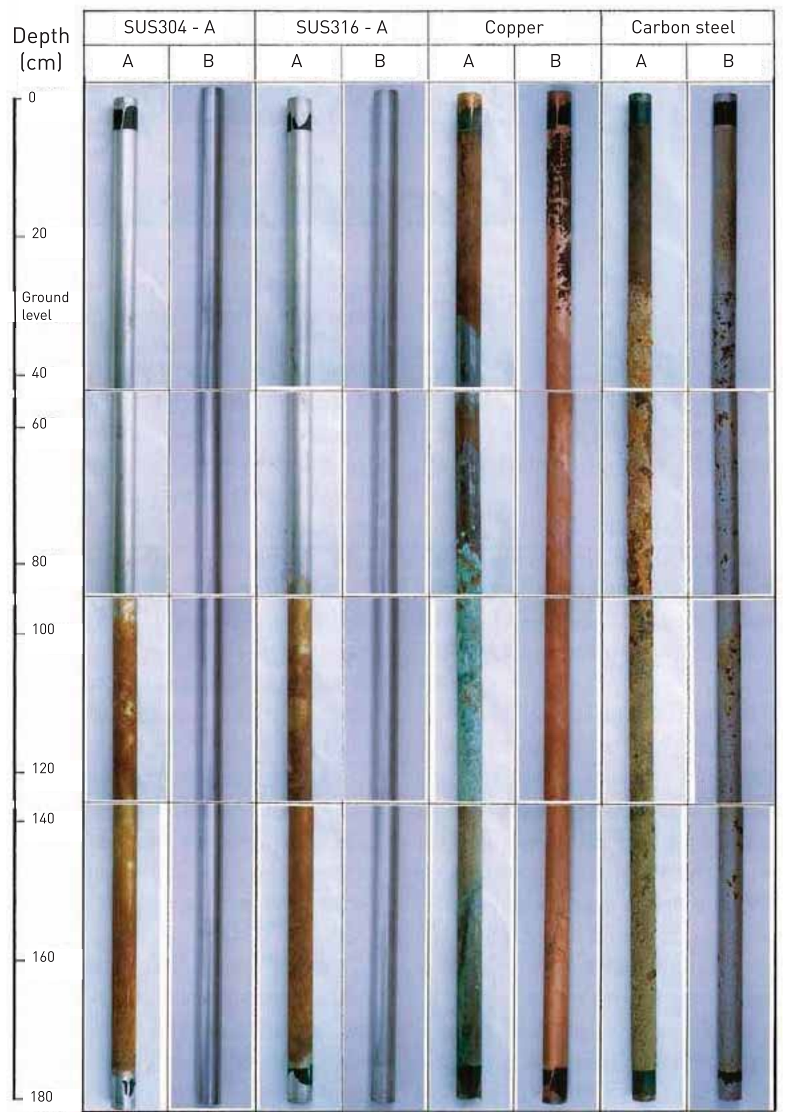
The tests showed that stainless steel had performed better in terms of strength and corrosion resistance with grade 316 performing better than 304.

The Cl- and SO42 concentrations in the soil were very high The tests showed no evidence of pitting corrosion on the 316 samples.

316 is a higher alloyed grade and therefore more expensive than 304, but the Tokyo Water Board decided that the greater cost is the cost of laying the pipes and that the risk of failure could not be tolerated because of a potential water shortage. As a result, the decisions to specify the stronger of the two grades of stainless steel irrespective of the initial costs difference, was economically justifiable.



Photos of the burial test results after 10 years of burial in Kushiro (North-East Japan) and Kuwana (Central Japan).



Burial test result from Okinawa.
A: After water cleaning
B: After pickling

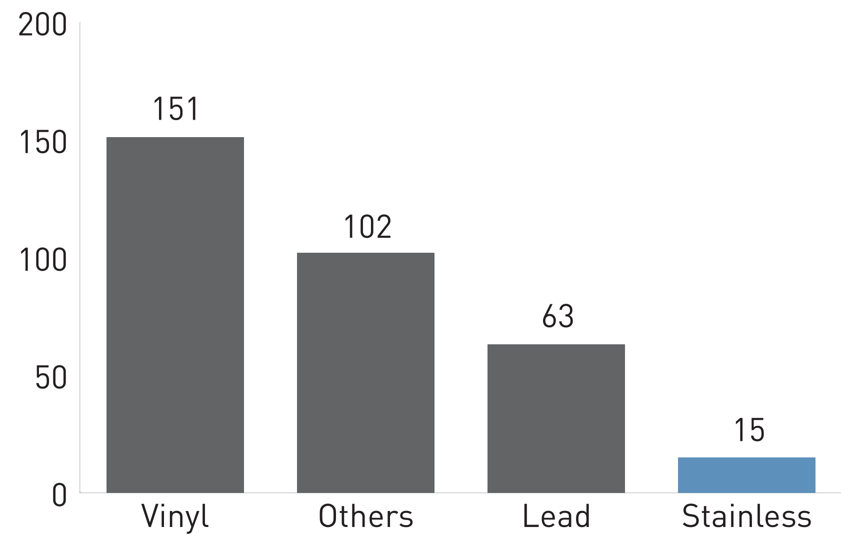
Corrugated Stainless Steel Pipes

The Tokyo Water Board discovered that many of their leaks had occurred at joints. The use of corrugated pipes allowed the installers to bend the pipes to the required shapes, thus reducing

the need for joints and elbows, but it also allowed the pipes to remain more flexible after installation, and therefore more capable of resisting seismic shocks.

Stainless Steel Corrugated Pipe
Source: Nickel Institute

This point was well proven after the Great Sendai Earthquake which struck the Northeast Coast of Honshu Island on 11 March 2011, with a magnitude of 9.0, which made it one of the strongest earthquakes ever recorded. Tokyo City lies on the boundary between the areas demarcated as having a strong to very strong impact (the earthquake was felt as far away as Beijing). After this incident inspections revealed that only 5% of the stainless steel pipes which had been installed were damaged.

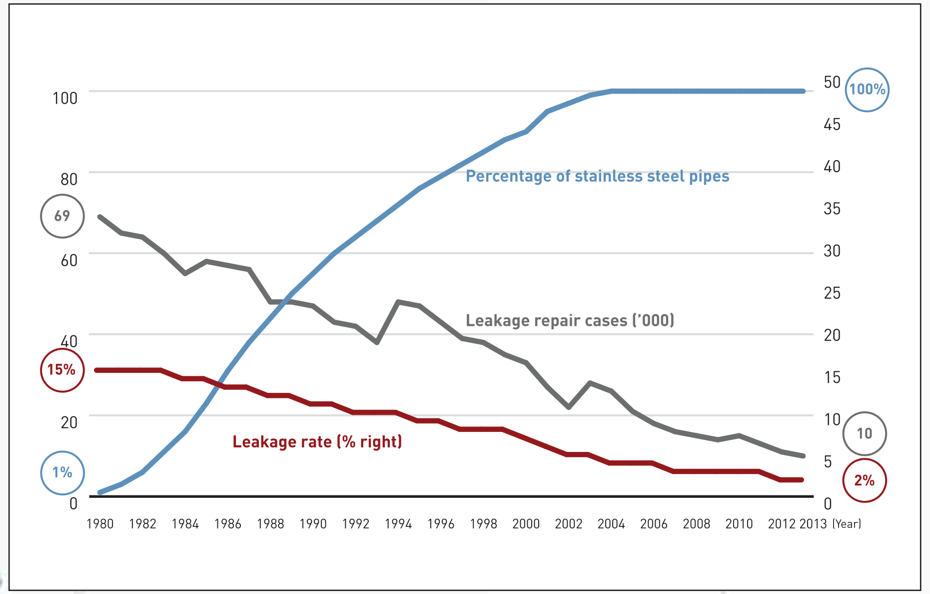


Number of damages after the Great Earthquake of 2011 per pipe material.

Tokyo tested corrugated stainless steel pipes from 1991 to 1998, before introducing them for all installations from 1998. In the early stages of testing, they used bronze fittings and discovered a risk of corrosion in the area of the joints. They therefore specified stainless steel for all joints, elbows, T-sections, valves and other fittings. The advantages provided by the use of stainless steel pipes were a reduction in the number of leaks; reduced maintenance; improved water quality; and a proven resistance to seismic activity.

The Tokyo Water Board has found no evidence of chemical residue deposits inside the pipes they have inspected.

Reduction of leakage



Stainless Steel Water Pipes in Seoul

Seoul Waterworks in Figures (2014)

Service population: 10.3 million

Annual distribution volume: 1,169 million m³ Water leakage rate: 2.5%

Stainless Steel Service Pipes in Seoul

Seoul began to replace its water pipe line sin 1984. 95.6% of the pipes have been replaced so far. The total replacement will be finished by 2018.

- Total length of pipe lines: 13,720 km
- Total length of pipe line replaced so far: 95.6%

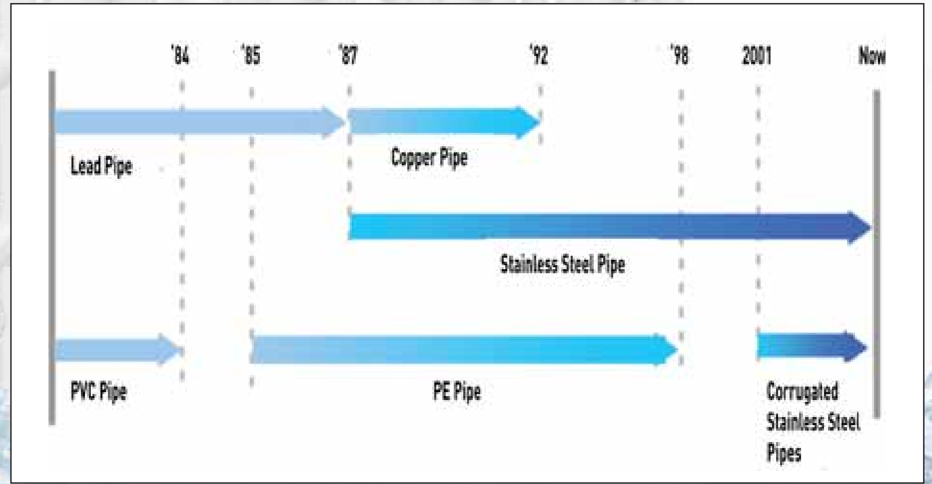
	1984-1993	1994-2003	2004-2013	2014-2018
Replaced pipes (in km)	5,518	5,668	2,006	536

Stainless steel was used to reduce corrosion and improve water quality. It was also used to reduce water losses through leakage because of its superior strength. From 1987 to 1993 stainless steel and copper pipes were used together, but from 1993 only stainless steel has been used. From 2001 corrugated pipes were introduced to reduce joints and to make assembly easier on site. Seoul discovered that the reduction of water losses, together with the improvement in water quality meant they could reduce the number of water treatment plants from ten to six, after this project. They found an improvement in the water leaks from 27% to 2.5%, even though the project still has one year left to run. This has enabled the city to reduce the number of repairs from 60,000 to 10,000 cases per year. It has also allowed the city to reduce its total water production (because there was less water wasted) from 7.3 million cubic meters per day to 4.5 million cubic meters, which is an excellent indicator of the water resource protection available from this project.

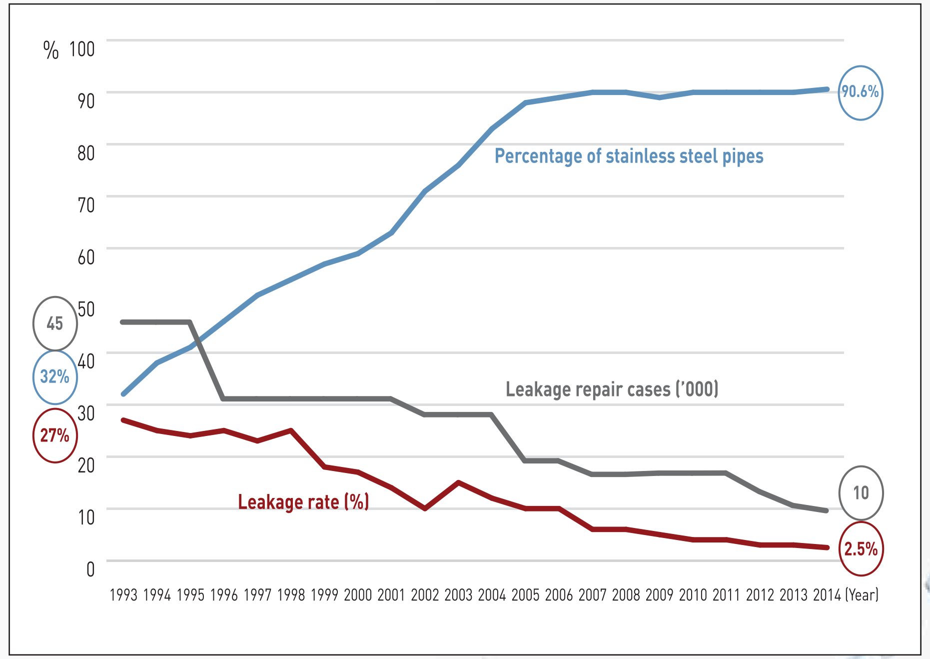
Seoul considered alternative materials, but their tests demonstrated that stainless steel was the preferred option. Contrary to the experience of their mentors, the Tokyo Water Board, Seoul decided to specify grade 304 stainless steel,

First, because their soils were shown to be less aggressive than those in Tokyo and 304 is a less expensive material.

Following the example of the capital, other Korean cities like Daegu, Incheon, Daejeon and Ulsan have also started to use stainless steel for their service pipes



Reduction of leakage



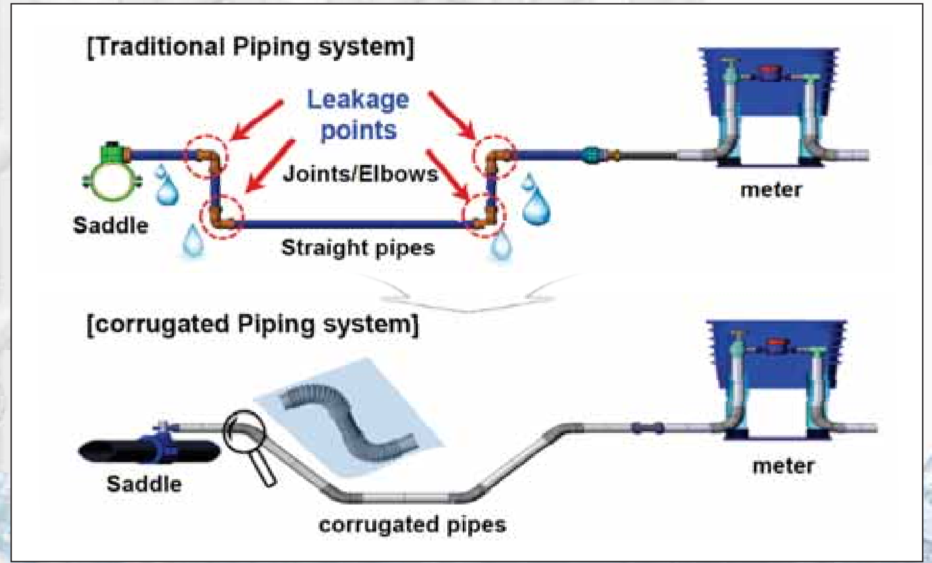
Sources

1. *Japan Stainless Steel Association*
2. *Nisshin Stainless Steel Tubing Co. Ltd.*
3. *Tokyo Water Board*
4. *Seoul Water Works*
5. *Ministry of Environment, Republic of Korea*
6. *International Molybdenum Association*

STAINLESS STEEL CORRUGATED WATER PIPELINE : AN ISSF PRESENTATION

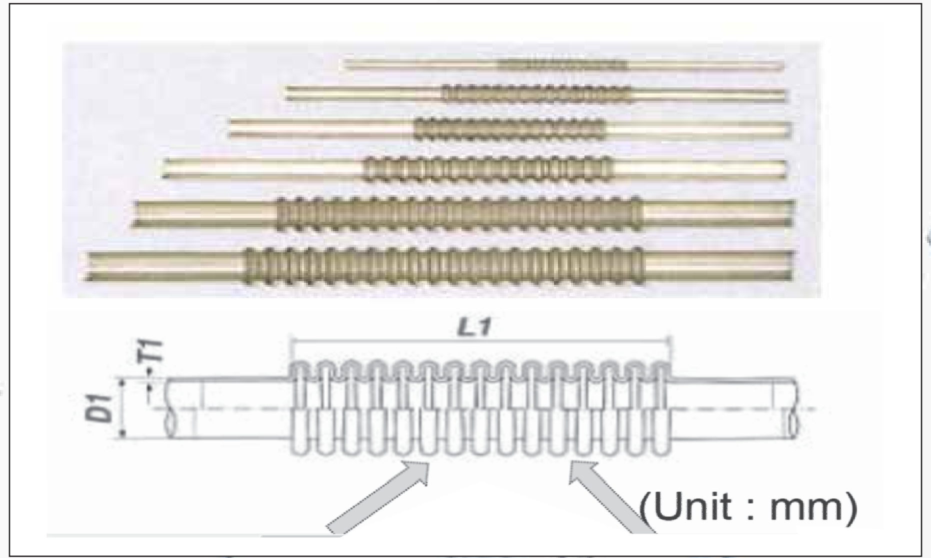
STAINLESS STEEL
CORRUGATED PIPES

Corrugated Stainless Steel Piping System



Details of Corrugated Stainless steel Pipes

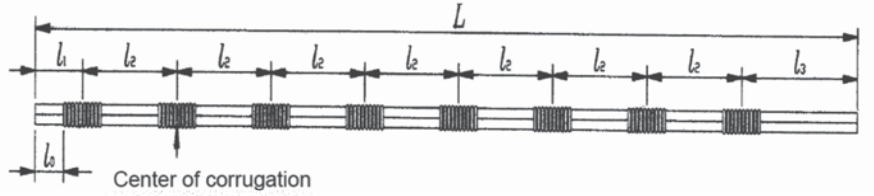
- Standard length: 4 meter
- Maximum length: 5 meter
- Diameter: 15~50mm for service pipes
- Thickness: 0.8~1.2mm
- Steel grade: SUS316 or 304



[JWWA G119, KWWA D118]

Diameter	Outer Diameter(D1)		Thickness(T1)		Length(L1)		# of Thread
	Standard	Tolerance	Standard	Tolerance	Standard	Tolerance	
15	15.88	0~0.37	0.8	± 0.08	80	± 10	15
20	22.22		1	± 0.1	120		
25	28.58						
30	34	± 0.34	1.2	± 0.12	153	± 20	
40	42.7	± 0.43			225		20
50	48.6	± 0.49					

Details of Corrugated Stainless Steel Pipes



[Size of corrugated stainless steel pipes]

(Unit : mm)

Diameter	L		l_1		l_2		l_3		l_0
	Standard	Tolerence	Standard	Tolerence	Standard	Tolerence	Standard	Tolerence	Standard
15	4,000	±0	190	+10 -0	475	±20	485	±0	150
20			210		475		465		150
25			210		475		465		150
30			230		470		480		153.5
40			265		460		515		152.5
50			265		460		515		152.5

Total length(L), # of corrugations, length of corrugation can be altered on request

Manufacturing of Corrugated Stainless Steel Pipe (Video)

Corrugated Stainless Steel Pipes (Korean Standard: KWWA D118)

Classification

Classification	Code	Application
Corrugated Pipe A	CSST-STS304	General water distribution pipes
Corrugated Pipe B	CSST-STS316	Distribution pipes requires more corrosion resistance

ManufacturingProcess

a) Straight pipes should be processed by arc welding or electric resistance welding

b) For corrugated pipes, corrugations should be processed by hydro forming or other ways and finished by solution treatment.

Properties

a) Pressure resistance: no leakage or damage when applying 2.5MPa pressure for two minutes on one end while closing other end of pipe.

b) Elongation and residual elongation: should conform to table 1.

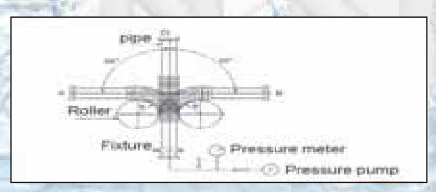
(Unit: mm)

Diameter	Elongation when 1.0Mpa	Residual elongation From 1 Mpa to 0 Mpa	Elongation When 2.5 Mpa
15~30	≤1.0	≤0.5	≤5.0
40,50	≤2.0	≤1.0	≤10.0

c) Bendability: no leakage or no malfunction after 10~20 times bending test in 0.1Mpa.

Diameter	# of bends
15/20/25/30	20
40/50	10

(Unit: mm)



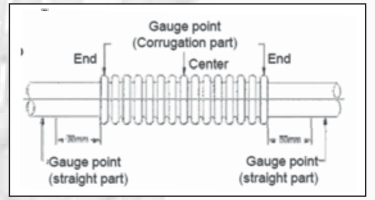
d) Flatness: no scratch or crack on surface after pipe was forced to 2/3XDiameter

e) Hardness: equal or lower than HV200 on corrugation section

f) Shock resistance: no leakage or malfunction after 2 kg steel ball drop test from 1 meter high

g) Thickness reduction ratio(r): equal or less than 20%

r = (1-t1/t2)x100 ,
where
r is reduction ratio,
t1 is lowest thickness of corrugation,
t2 is lowest thickness of straight pipe



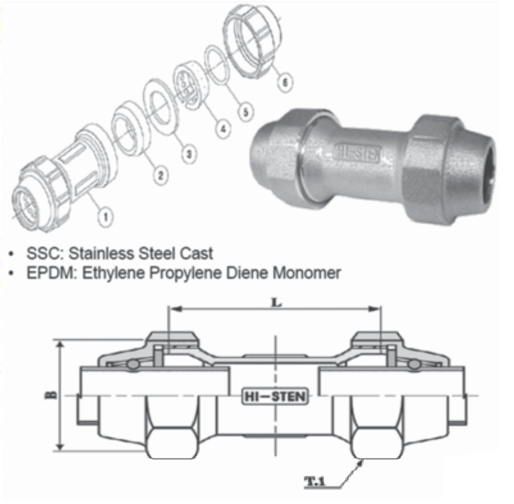
h) Bio-elution: Must conform with national regulations

Details of Sleeve-in joint

- Made of cast stainless steel

Item	Description	Material
1	Body	SSC13/14
2	Packing	EPDM
3	Washer	STS304/316
4	Ball Guide	STS304/NYLON6
5	O-Ring	EPDM
6	Nut	SSC13/14

(mm)	L	B	T.1
13su	80	41.0	Hexagonal
20su	80	47.0	Hexagonal
25su	80	55.5	Hexagonal
30su	90	61.5	Octogonal
40su	90	71.0	Octogonal
50su	90	78.0	Octogonal
60su	90	90	Octogonal



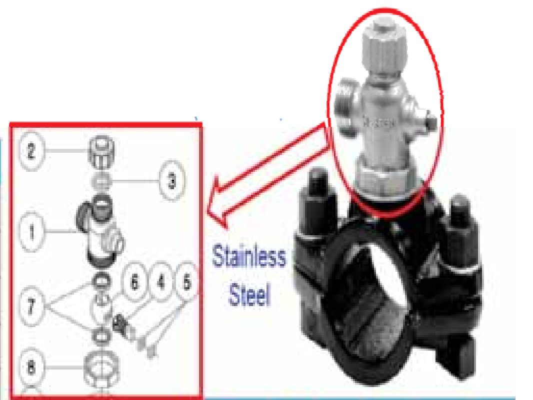
- SSC: Stainless Steel Cast
- EPDM: Ethylene Propylene Diene Monomer

Stainless Steel Joints/Fittings

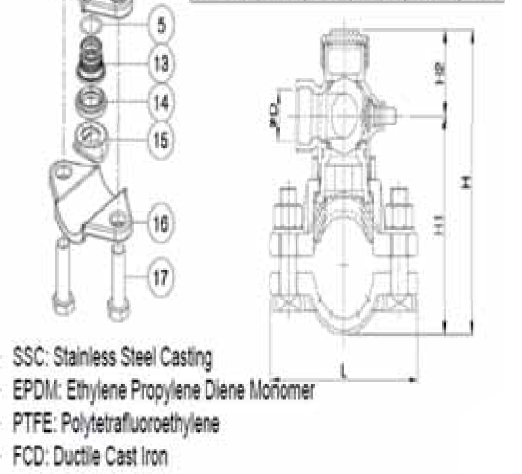
Details of Snap tap with Saddle

-Made of Cast Stainless Steel + Carbon steel(Ductile)

Item	Description	Material
1	Body	SSC13/14
2	Cap	SSC13/14
3	Cap Packing	EPDM
4	Stem	STS304/316
5	O-ring	EPDM
6	Ball	STS304/316
7	Seat	PTFE
8	Lock Nut	SSC13/14
9	Insulation Pad	PE
10	Nut	FCD450
11	Washer	SS400
12	Saddle	FCD450
13	Insert	SSC13/14
14	Insulation Guide	PE/EPDM
15	Upper Packing	EPDM
16	Band	FCD450
17	Bolt	FCD450



Size (mm)	ØD	L	H	H1	H2
100x25	29.5	204	231.8	182.8	49



- SSC: Stainless Steel Casting
- EPDM: Ethylene Propylene Diene Moñomer
- PTFE: Polytetrafluoroethylene
- FCD: Ductile Cast Iron

ROUGHNESS TEST FOR STAINLESS STEEL TUBES IN THE TRANSPORTATION OF WATER

Roughness Test for Stainless Steel
Tubes in the Transportation of Water

Centro Inox in cooperation with The Department of Civil Engineering at the Polytechnic of Milan (Prof. Orsi) has carried out roughness test for stainless steel tubes for transporting water, in particular drinking water.

The aim was to compare the behaviour of the PVC and carbon steel tubes, ingeneralused for the distribution of water, with welded stainless steel tubes with an internal 2B finish. For PVC and carbon steel there are data for designers about the flow resistance, but for stainless steel these data are not available. The results are satisfactory and they demonstrated that when the waterflows in the stainlesssteel tubes the friction is lower than other materials. Consequently if the designer will use the stainless steel tubes could have some advantages.

Technical Specifications

AIM: COMPARED THE BEHAVIOUR OF CARBON STEEL TUBES AND PLASTIC TUBES WITH STAINLESS STEEL TUBES

The two sets of tests have the main purpose of evaluating the roughness in stainless steel tubes and pipes in order to assess their performance compared with the "smooth tube" condition. We shall subordinately evaluate the opportunity and possibility to express the dropping uniform motion J, i.e. the reduced resistance λ through a monomial expression, similarly to Blasius' expression, which is originally limited to values $Re < 10^5$.

The tests will be performed on two cold drawn 2 mm thick stainless steel tubes with external diameters of 76.1 and 129.0 mm respectively.

As is known, these kinds of tests consist in the evaluation of the hydraulic roughness starting from a section of the pipe and by relating them to the system geometry (diameter D and length L), to the transiting capacity, and hence to Reynolds number. The reference relation is the Colebrook-White formula, which after having been solved compared to the roughness, provides

$$\varepsilon = 3{,}71\, D\,(10^{-1/(2\sqrt{\lambda})} - 2{,}51/(Re\sqrt{\lambda})$$

Re = VD/v with kinematic viscosity (v) of water the value of which, depending on the temperature (C°), will be expressed, in the interval 5 C° < t < 30 C°, through the interpolar formula: $10^7 v = 17{,}302\, e^{-0{,}0255t}$

$J = \Delta H/L_u$ ΔH = q piez upstream-q piez downstream

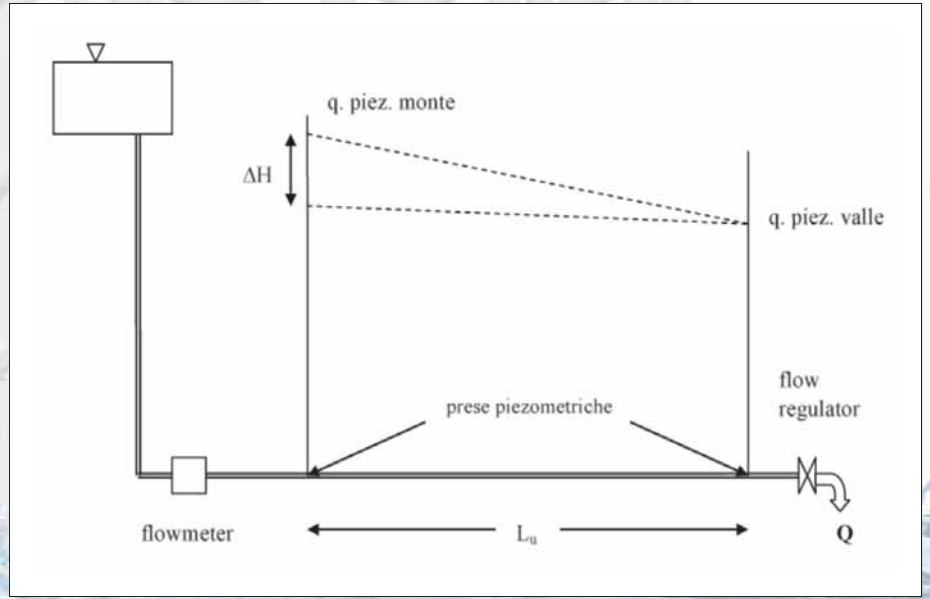
$\lambda = J\, 2gD/V^2$

The test lab is located in the laboratory of hydraulics "G. Fantoli" of the Politecnico di Milano. The system allows to convey the necessary water flows with a difference in level, between feed and discharge caissons, of about 14 m. Water at room temperature is used.

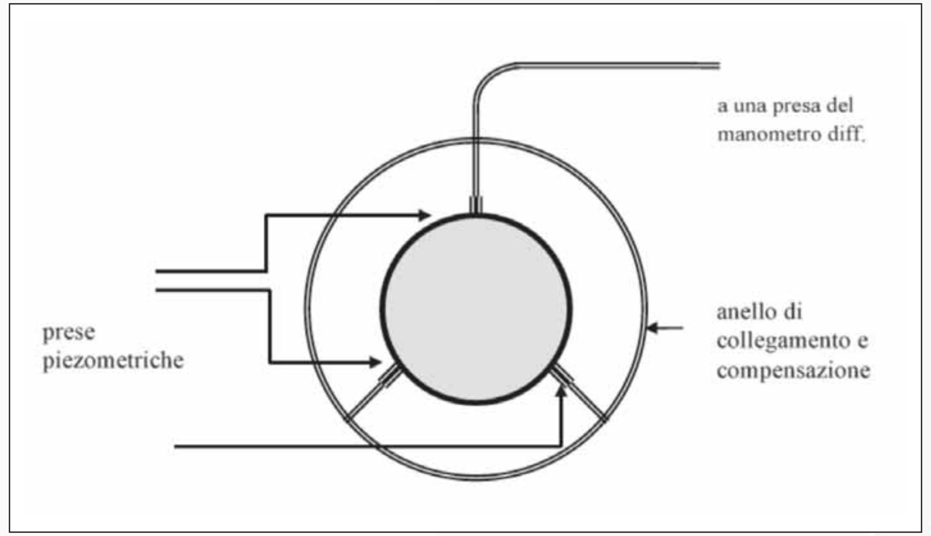
The available pipe length is 6x3 =18 m, i.e. a set of three tubes with orbital welding, considering the sections to obtain uniform flow, the useful length L_u is reduced to about 14.5 -16 m. Basing on preliminary results, it will be possible to work at speeds ranging from 0.5 e 5 m/s; In terms of Reynolds number from about 30 x10^3 to 350 x 10^3 for the pipe with the smaller diameter, and between 60 x10^3 and 600 x 10^3 for the pipe with the greater diameter.

Water flows will be measured through an electro-magnetic flow-meter (Endress-Hauser) placed upstream the line, while for the differential pressures a differential pressure gauge will be used (Endress-Hauser) connected to two triads of piezometric sockets at the end of the useful section of the pipe.

Diagram of the Experimental Installation



Detail of the Upstream and Downstream Piezometric Sockets



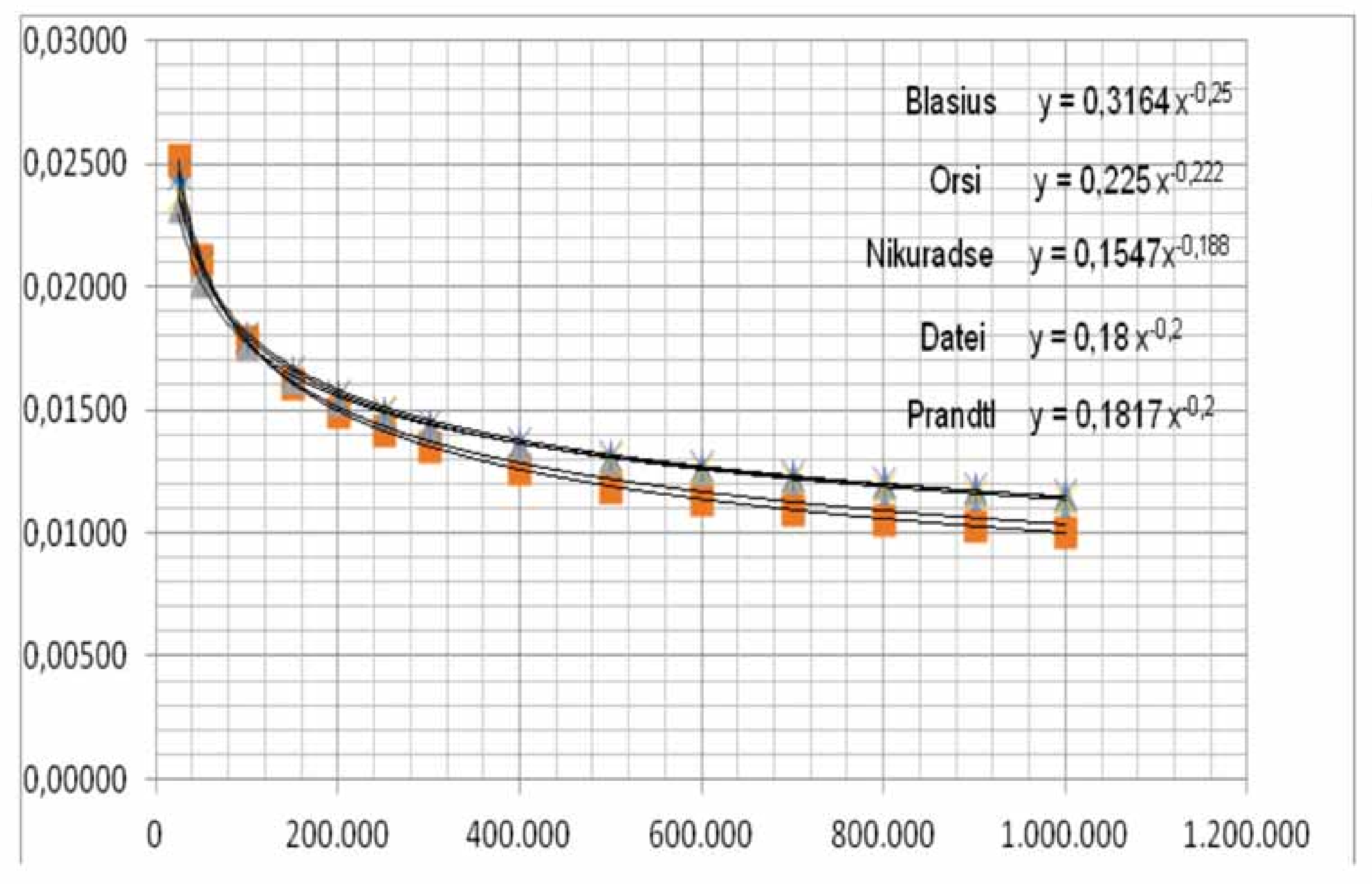
The Lab Area Devoted to Tests

Results

The tests described made it possible to identify at rend of there duced resistance λ in function of the Reynolds number, that can be represented through the monomial expression:

$$=0{,}225\ Re^{-0{,}22}.$$

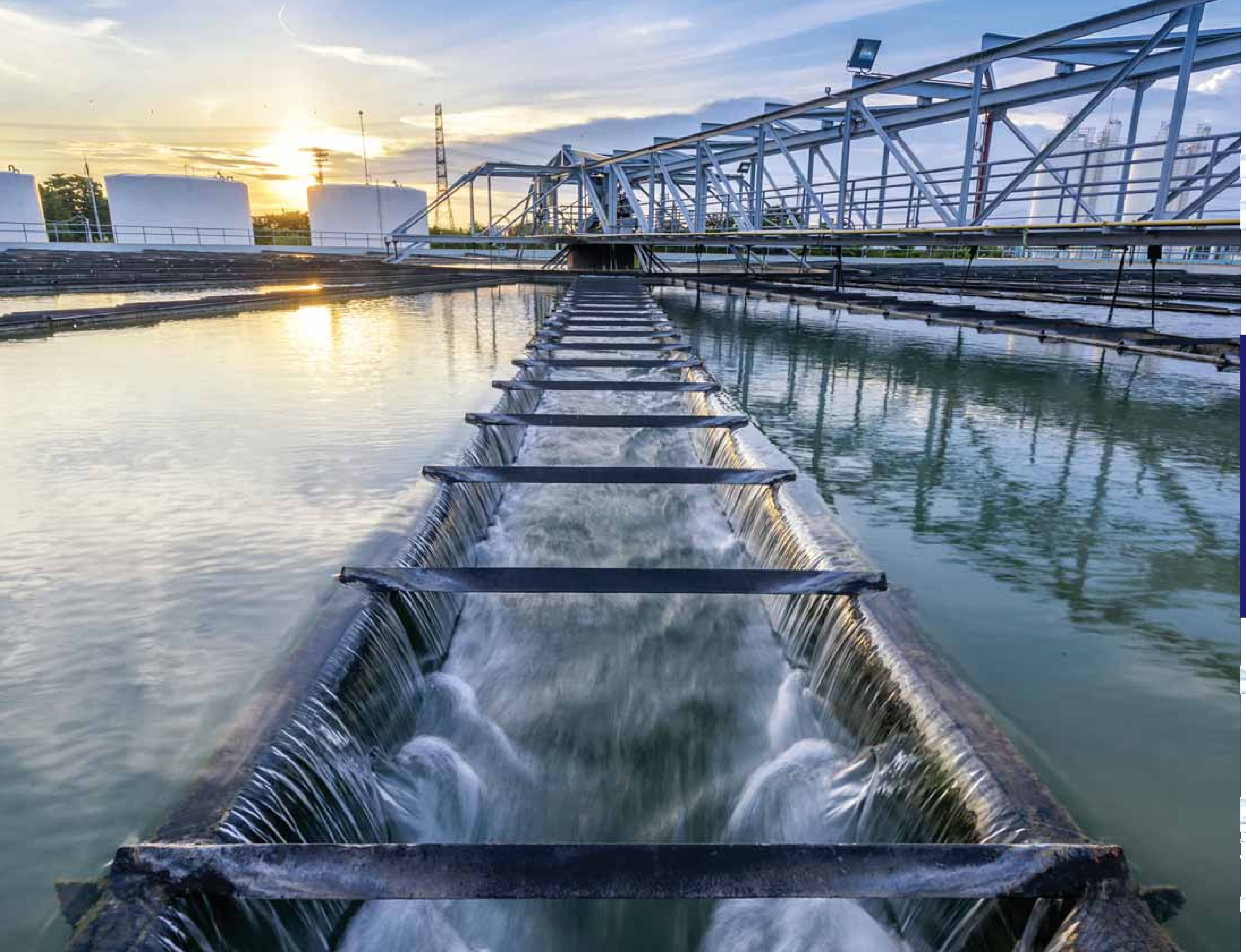
Up to about 150,000/200,000 of Reynolds numbers there are no big variations but on higher values we can note a deviation of the curve, verified, which turns out to be roughly half among the theoretical curve of Blasius and all the others. This means that stainless steel allows better roughness test and the improvement is sensible when the Reynolds number is over 200,000. From the design point of view and the choice of the material, this is definitely an advantage. Therefore, in proposing stainless steel pipes for the potable water sector, in addition to the known advantages: corrosion resistance, reduced maintenance, hygiene (inertia to the water), there is also a need to take into account such performance, which allows, for example, less absorption of energy in the pumping stations, decreasing the required slopes, etc.



Source: CENTRO INOX, SSDA Workshop, Tokyo 15 -16 May 2017.

WATER IS LIFE

STAINLESS STEEL
IN
WATER TREATMENT PLANTS



GUIDELINES FOR THE USE OF STAINLESS STEEL IN MUNICIPAL WASTE WATER TREATMENT PLANTS

Guidelines for the use of stainless steel in municipal waste water treatment plants

A.H. Tuthill
S. Lamb

Stainless steel piping has served as the standard material of construction for municipal waste water treatment plants (WWTP's) built in the United States over the past 25 years. A typical plant is shown in *Figure 1*.

Since the late 1960's, over 1600 municipal WWTP's have been built using stainless steel aeration, digester gas and sludge transfer piping, as well as stainless steel slide gates, valves, tanks, screens, handrails and other equipment. Stainless steel was selected originally over galvanized and painted carbon steel in order to reduce the higher maintenance and replacement costs associated with these less corrosion resistant materials. Overall experience has been good to excellent (1). This article reviews the suitability and performance of the several grades of stainless steels that have been used or considered for waste water treatment plants and identifies guidelines that will assist the user to obtain the best results from the stainless steel selected for these plants.

Figure 1 Waste water treatment plant. Canegrate, Italy.

The austenitic grades used in waste water treatment plants have 16-20% Cr, 8-14% Ni and the Mo containing grades, 2-3% Mo. *Table I* shows the common name, the UNS number, the British, German and Swedish designations and compositions for the wrought grades. *Table II* shows the substantially higher ASME allowable design stresses for stainless steel pipe compared to those for carbon steel pipe, especially when stainless pipe is supplied as a dual-certified product, thereby allowing the use of the higher design properties while maintaining the low carbon for weldability.

Table II ASME allowable design stresses (ksi)

		Temperature 0-100°F
Stainless steel welded pipe		
ASTM A 312	Type 304	16.0
	Type 304L	13.3
	Type 316	16.0
	Type 316L	13.3
Carbon steel pipe		
ASTM A 53	Seamless type A	12.0
	Seamless type B	15.0
	Welded type A	10.2
	Welded type B	12.8

Table I Alloy identification and compositions %

Common Name	UNS NO.	British BS	German DIN	Swedish SS	EURONORM EN	C	Cr	Ni	Mo	Fe
304	S30400	304S31	1.4301	2333	1.4301	0.08	18.0	10.0	–	Bal.
304L	S30403	304S11	1.4306	2352	1.4306	0.03	18.0	10.0	–	Bal.
316	S31600	316S31	1.4401	2347	1.4401	0.08	17.0	12.0	2.0-3.0	Bal.
316L	S31603	316S11	1.4404	2348	1.4404	0.03	17.0	12.0	2.0-3.0	Bal.

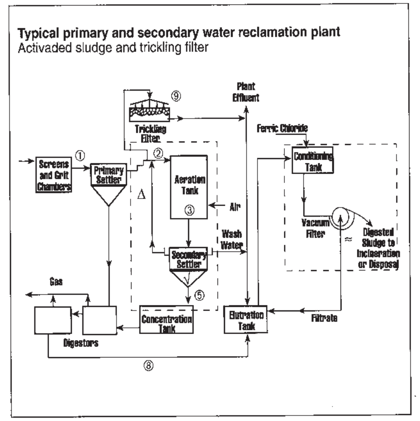


Figure 2 Typical flow diagram for a waste water treatment plant.

The low carbon grades, Types 304L and 316L, are used for welded construction. These low carbon grades are designed to be resistant to intergranular corrosion after welding without further heat treatment. The higher carbon content grades have slightly higher strength and are used primarily for pump shafts and valve stems where welding is not involved and the higher strength can be used to advantage in the design. The Mo containing grades are more resistant to localized corrosion and are preferred for more aggressive conditions or simply for greater insurance against unusual conditions which may exist from time to time. The cast equivalent grades have comparable corrosion resistance and comparable mechanical properties.

WWTP ENVIRONMENTS

Figure 2 shows a typical flow diagram for a waste water treatment plant, indicating the locations where corrosion test specimens were exposed to actual plant conditions for different periods of time. These tests were run in different plants during the 1960's and early 1970's with the results being analyzed and reported by the International Nickel Company (Inco).(2)

Table III WWTP environments

Plant Location	Flow Rate	Feedstock	Other Comments
1. Municipal Waste Feed	N.A.	Raw untreated sewage	BOD 175-300ppm Suspended solids 220-650ppm O_2 140ppm
2. Mixed Feed & Activated Sludge	2-3 ft/s	70% sewage 30% active sludge + H_2S	—
3. Aeration Tanks	violent agitation	70% sewage 30% active sludge	—
4. Clarifier (secondary settlers)	Low velocity	Activated sludge with some effluent	—
5. Concentrated Active Sludge	Fairly high	—	—
6. Vacuum Filter to Disposal	No aeration 1 ft/s	Activated sludge to vacuum filter	Some ferric chloride additions
7. Discharge Effluent	2 ft/s moderate aeration	—	—
8. Sewage Effluent	4-5 ft/s extensive aeration	Can have high Chloride and dissolved solids	
9. Trickle Filter	—	—	aeration high

Note: Typical temperature 68-77°F. Typical pH 7.4-7.7.

Table IV Corrosion rates in WWTP environments, mpy (mm/yr)

Plant Location	Type 304		Type 316		1010 Steel	
1. Municipal Waste Feed	<0.1[1]	(<0.002)	<0.1[1]	(<0.002)	3.0 - 9.0[2]	(0.075- 0.225)
2. Mixed Feed and Activated Sludge	<0.1	(<0.002)	<0.1	(<0.002)	4.6[2]	(0.117)
3. Aeration Tanks	<0.1	(<0.002)	<0.1	(<0.002)	1.5 - 5.0[2]	(0.037- 0.127)
4. Clarifier (secondary settlers)	<0.1[1]	(<0.002)	<0.1	(<0.002)	3.0 - 6.4[2]	(0.075- 0.162)
5. Concentrated Active Sludge	<0.1[1]	(<0.002)	<0.1	(<0.002)	4.8[2]	(0.122)
6. Vacuum Filter to Disposal	<0.1[1,2]	(<0.002)	<0.1[1]	(<0.002)	3.7 - 8.3[2]	(0.094- 0.210)
7. Discharge Effluent	<0.1[1]	(<0.002)	<0.1	(<0.002)	6.3[2]	(0.160)
8. Sewage Effluent	<0.1[2]	(<0.002)	<0.1	(<0.002)	1.8[2]	(0.046)
9. Trickle Filter	<0.1	(<0.002)	<0.1	(<0.002)	2.2	(0.056)

Averaged corrosion rates over 168 - 732 days exposure
Corrosion rate - mpy (mm/yr)
[1] Evidence of crevice corrosion attack
[2] Pitting attack

TABLE V MWWTP corrosion tests - mpy (mm/yr)
Location 6: activated sludges in dewatering and vacuum filter

Environment	Type 304	Type 316	1010 Steel
Activated Sludge to Vacuum Filter (No Aeration)	<0.1 (<0.002)	<0.1[1] (<0.002)	6.3[2] (0.16)
Conditioning Tank + 250-300 ppm Ferric Chloride	0.16[1,2] (0.004)	<0.1[1,2] (<0.002)	8.3[2] (0.21)
Filtrate From Dewatering of Activated Sludge (Moderate Agitation)	<0.1[1] (<0.002)	<0.1 (<0.002)	3.7 (0.094)
Filtrate From Dewatering and Elutriated Sewage Sludge (Extensive Aeration) + 2% by Weight Ferric Chloride (pH 5.5 - 6.0)	<0.1[1,2] (<0.002)	<0.1[1] (<0.002)	NA

Averaged corrosion rates over 168-732 days exposure
[1] Evidence of crevice corrosion attack [2] Pitting attack

Tables III, IV and *V* summarize data for Type 304, Type 316 and 1010 carbon steel from the INCO test rack exposures. The plant location for each test is identified by the numeral that corresponds to those shown in the flow diagram. Corrosion rates for carbon steel varied from 3 mpy (0.075mm/yr) in the raw incoming sewage to 16 mpy (0.4mm/yr) in the clear effluent. The greater the oxygen, the greater was the corrosion for carbon steel (corrosion rates are in direct proportion to the amount of oxygen reaching the surface of the carbon steel). The corrosion rates of carbon steel in all locations are high enough to require continual maintenance and early replacement. Galvanizing and coatings may extend the life of carbon steel piping systems for several additional years, but they still do not offer an optimum solution to long term protection in WWTP environments. These coatings can become damaged or sacrificial in nature.

Stainless steel Types 304/304L and 316/316L are the principal materials used for bar screens, grit removers, weirs, bolting, slide gates and aeration basin, digester and sludge piping in municipal waste water treatment plants today. For the past 20 years or more, these materials have become standard materials of construction, based upon the field testing undertaken by International Nickel. Reference to *Tables III, IV* and *V* show weight loss corrosion rates for Types 304 and 316 stainless steels were <0.1 mpy, except in one activated sludge exposure reported in *Table V*, which will be discussed later. A corrosion rate of <0.1 mpy indicates that material would be expected to have a useful life well in excess of 20 years.

These very low corrosion rates mean that stainless steel equipment does not have to be specified with a "corrosion allowance" added to the design wall thickness, as must be done for carbon steel and ductile cast iron equipment. This leads to a significant saving in weight/material when stainless steel is specified.

Evidence of crevice corrosion initiation was reported on some of the stainless steel specimens. This type of corrosion can occur in localized areas, where "shielded" or "creviced" areas exist, e.g. at bolted joints, at incomplete welds or beneath adherent sludge deposits. To minimize this type of attack, crevices should be eliminated wherever possible, all weld joints fully penetrated and periodic cleaning scheduled to remove adherent deposits. In the case of aeration basins, deposit removal is usually accomplished when they are taken out of service for odour control cleanings. These precautions have resulted in long term, continuing service with no significant problems. Agitation and oxygenation in the aeration basin during operation further benefit the performance of stainless steels.

Atmospheric Corrosion Resistance

As chromium is added to steel, corrosion resistance increases. The amount of chromium needed to make stainless steels "stainless" can be defined by the weight loss of steels with varying amounts of chromium (3). Faulrings's data indicates that the weight loss for steels with 12.5% and higher chromium contents is quite low after 25 years exposure to marine atmospheres. These "straight chromium" grades of stainless steel (ferritic and martensitic), develop a surface layer of rust making them unsuitable for most atmospheric applications, where appearance is important. By contrast, the austenitic grades Types 304 and 316 containing 8-10% nickel, are more resistant and usually retain their bright appearance in atmospheric exposures for many years.

Hydrogen sulfide gas is generated in the digesters and throughout much of a WWTP, contributing to the corrosion that occurs in copper alloys, aluminum and carbon steel. According to De Renzo, the corrosion rate of Type 304 and Type 316 in moist H_2S is <0.1 mpy (<.0025mmy), indicating a negligible corrosion rate (4). Type 304L is the standard material used for digester gas piping and has performed well.

Although there is no intentional exposure to moist chlorine vapours, several cases of general pitting have been reported on the outer surface of piping in confined location with poor ventilation near chlorine storage areas. Both Types 304L and 316L stainless steel are subject to staining and general pitting in atmospheres where moist chlorine vapours can accumulate and condense, usually in enclosed areas. These occurrences were remedied by appropriate ventilation or minimized through regular water spraying and cleaning of the stainless steel surfaces.

Chlorine - Ozone

Stainless steels are generally resistant to chlorine at the concentrations normally encountered in waste water treatment plants. *Table VI* gives test specimen exposure data for type 1010 steel, cast iron and Types 304 and 316 stainless steel in chlorinated fresh waters with typical residual chlorine concentrations(5). Both 304L and 316L exhibit excellent corrosion resistance in inland waters with up to 2 ppm residual chlorine, whereas corrosion rates for carbon steel and cast iron are doubled. For continuous exposure to 3-5 ppm residual chlorine, the data indicate that Types 304/304L become prone to crevice corrosion and Type 316L would be a more conservative choice. Stainless steels are not suitable for chlorine injection systems which may contain fifty to several hundred ppm chlorine.

Ozone is an increasingly common alternative oxidizing agent which can be used separately or in conjunction with chlorine. Type 316 has been the preferred material of construction for ozone generators, although background and data are lacking as to why Type 316L was originally selected over Type 304L.

Other Chemical Additives

Ferrous sulfate is a chemical that is frequently added in WWTP's: De Renzo also gives the corrosion rate of Types 304 and 316 in ferrous sulfate, contaminated with sulfuric acid at pH 1 - 2.5 (spent pickle liquor), as <0.8 mpy (<0.02 mm/yr) which is indicative of excellent resistance. In WWTPs, sulfuric acid is not normally present, and consequently, the corrosion rate for stainless steel in acid-free ferrous sulfate environments will be negligible.

Ferric chloride is sometimes used for flocculation in the conditioning tank where sludge is further concentrated and dewatered for incineration and disposal. Types 304 and 316 specimens installed in activated sludge location 6 (Table III), where there were 250-300 ppm ferric chloride present, suffered both pitting and crevice corrosion. The data in Table V indicates Type 316 is slightly more resistant to ferric chloride than Type 304 and might represent a more conservative choice downstream of ferric chloride injection points, where significant concentrations of ferric chloride may be present. However, despite the adverse test data, Type 304 piping is normally used to handle treated, flowing sludge.

Microbiological Influenced Corrosion

Welds in the standard grades of stainless steels, and areas adjacent to welds, are occasionally subject to microbiological influenced corrosion (MIC) in stagnant and slowly moving waters. One example of MIC attack occurred on Type 409 (11% chromium) stainless steel frames of experimental rotating biological contractors (RBC's) in one WWTP. *Figure 3* shows an RBC unit being disassembled. *Figure 4* shows a MIC mound more or less centered on the weld of the frame. The RBC's, with their stainless steel frames slowly rotating in and out of the sludge at about 2 rpm, create conditions almost ideal for MIC. Other instances of MIC in WWTP's are rare.

The unusually low incidence of crevice corrosion and MIC in municipal waste water treatment plants may well be due to several of the following factors favouring good performance:

Figure 3 Type 409 stainless steel Rotating Biological Contractor (RBC) disassembled with MIC attack on arms.

Figure 4 MIC mound at welded cross beam.

Table VI Corrosion behaviour of 1010 steel, cast iron and Stainless steel in chlorinated fresh waters

Chlorine Residual (mg/L)	Corrosion Rates mpy (mm/yr)		Exposed Surface - Max. Pit Depth (mils)		Maximum Depth Crevice Attack (mils)	
	1010 Steel	Cast Iron	Type 304	Type 316	Type 304	Type 316
0	1.4 (0.004)	1.7 (0.004)	0	0	0	0
0.8-1.0	2.5 (0.064)	3.0 (0.075)	0	0	0	0
2	3.4 (0.086)	3.4 (0.086)	0	0	0	0
3 - 5	10.7 (0.272)	N.A.	<1	0	4-14	1-5

- Removal of heat tint scale by pickling or mechanical cleaning on the exterior of the aeration piping exposed to the sludge in aeration basins.
- Smooth contoured and crevices free circumferential butt welds of piping exposed to sludge.
  (Note: Removal of heat tint (6) and the absence of crevices have been found to significantly enhance resistance to MIC and other forms of localized corrosion)
- Aeration and agitation of the sludge reduces the tendency of the sludge to adhere to the surface of the piping.
- Thorough wash down cleaning of the sludge from the outside diameter of the piping when the aeration basin is taken out of service.

General Experience

Most, if not all, of the stainless steel piping installed in the older WWTP's, built in the 1960's and 1970's, as well as those built later, are still in service. A typical application is shown in *Figure 5* where stainless steel aeration piping is used in a sludge aeration basin. Stainless steel has performed better in actual service than might have been predicted from the test specimen exposure data summarized earlier, especially where good housekeeping practices have been employed.

A few instances of under-deposit corrosion have occurred on the outside of submerged aeration piping. In these instances, the corrosion occurred under small adherent residues that had not been completely removed in the normal cleaning of the aeration basins.

Figure 5 Aeration piping sludge tank.

As noted in the test rack exposures, corrosion occurred on specimens in activated sludge, where ferric chloride was being added. However, stainless steel sludge piping has generally performed well in handling activated sludge environments, except in one instance where crevice corrosion was recently reported in a sludge line in an open recess at an O-ring type mechanical joint and in an elbow in the same line. Sludge became packed in the open recess and led to severe crevice corrosion around the O-ring. Low flow and stagnant conditions apparently persisted long enough to allow corrosion to initiate under the accumulated deposit that was packed into this open recess in the piping. To minimize under-deposit corrosion, stagnant and low flow conditions should be avoided in sludge lines. Free flowing conditions will assist in reducing deposit formation.

Crevice corrosion can also occur in some soils. External corrosion of buried stainless steel is dependent upon soil analysis and soil resistivity. Soils differ in their corrosiveness depending upon the wetness, pH, aeration, stray currents and surface drainage. The potential for crevice corrosion of buried stainless steel piping tends to increase as the moisture content of soils increases and is greatest in swamps, under river crossings, and in wet soils. Based on tests run in Japan, stainless steels have performed well in a variety of soils and especially soils with high resistivity(7). The Japanese have had great success with buried stainless steel connectors bringing potable water from the submain in the street to the dwellings in the city of Tokyo. Almost half a million connectors are now in service with no known corrosion problems since installation began on a major scale in 1980. For wet soils and critical piping, stainless steel pipes can also be cathodically protected, as is standard practice for buried piping.

Procurement And Specifications

Most of the problems that have been encountered with stainless steel piping in WWTP's arise in procurement, design, fabrication and erection. The common specifications for welded austenitic stainless steel piping and fittings are shown in *Table VII.*

Table VII Comparison of stainless steel piping specifications

Specifications	ASTM A312	ASTM A778	ASTM A409
Coverage	Welded & Seamless	Welded	Welded, large diameter, light walled pipe
Fittings Specifications	ASTM A403	ASTM A774	ASTM A403/A774
Sizes	1/8" - 30"	3" - 48"	14" - 30"
Wall Thickness	SCH 5S - 80	0.062" - 0.5"	SCH 5S - 10
Solution Anneal	Required	As - Welded	Optional
Filler Metal Additions	Autogenous Or Matching	Matching	Matching
Mechanical Testing	Tensile & Weld Face Bend	Tensile & Weld Guided Bend	Tensile & Weld Guided Bend
Hydro Test	Required	Optional	Required
Scale	Removal Required	Removal Optional	Removal Required

ASTM specifications A312 (pipe) and A403 (fittings) define the welded austenitic stainless steel pipe and fittings developed for use in aggressive corrosion environments, typical of the chemical and other process industries. Most of the common stainless steel alloys are covered by these specifications in both the low carbon and regular grades, with sizes ranging from 3 mm (1/8") to 0.75 m (30") in diameter. ASTM specification A312 requires a final solution anneal and removal of heat tint scale.

ASTM specifications A778 (pipe) and A774 (fittings) were developed for less severe services where the low carbon and stabilized grades are normally used in the as welded condition. (Only low carbon and stabilized grades are included in this specification.) The size ranges covered by these specifications are from 75 mm (3") to 1.22 m (48") in diameter. Solution annealing after welding is not required by these specifications since only the low carbon and stabilized grades of stainless steel are covered. Although removal of heat tint scale is left optional, it should be removed and be specified in procurement documents in order to avoid potential corrosion problems that have occurred on unpickled pipe with heat scale remaining on its surface.

Design And Fabrication

ASTM specifications do not cover circumferential butt welds required for shop or field fabrication of the piping. The user, or the engineering firm handling design and construction, must develop in house welding specifications. It is important that these specifications include:

1) A requirement for full penetration and smooth ID circumferential welds.
2) Use of inert gas backup on the inside of the piping during welding to minimize oxidation and heat tint.
3) The use of a matching composition or higher Mo content filler metal.
4) Protection of the piping with well secured protective end caps to minimize contamination during shipment and clean indoor or outdoor storage.
5) Ensure clean indoor or outdoor storage areas (off the floor/ground).
6) Removal of heat tint scale from the OD of aeration basin piping.

The circumferential welds in those areas exposed to the handling of sludge - the OD of the aeration piping and the ID of the digestor and sludge piping, should be free of crevices and fully penetrated.

Some piping systems, such as aeration piping, are subject to vibration in service. Although Types 304 and 316 exhibit excellent fatigue strength with high endurance limits (8) of approximately 35,000 psi, see S-N curve in *Figure 6*, it is important to carefully design areas such as transition sections or where intersecting members of an assembly occur. These areas represent the weakest point of the structure where vibrational stresses tend to concentrate.

Consequently, the use of saddles and pull-through branch connections will allow joints to be made away from these intersecting connections. The use of a saddle will allow a full-penetration weld to be made in the connector, shown in *Figure 7*, and allow the connecting weld to the header to be moved away to form a more traditional pipe weld. A design of this nature eliminates the need to complete a weld in an otherwise tightly designed intersecting joint, which may result in flux entrapment when using manual arc welding techniques or the creation of crevices (incomplete weld penetration) on the underside of the joint.

The use of supporting gussets for the header would be beneficial in minimizing the vibrational stress effects for this typical aeration piping application.

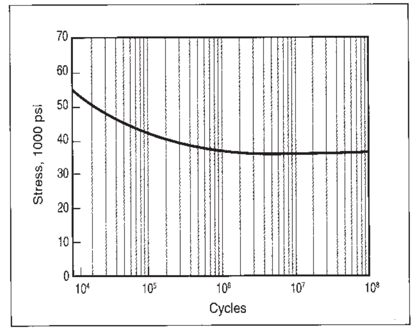


Figure 6 S-N curve in bending for annealed, Type 300 stainless steels.

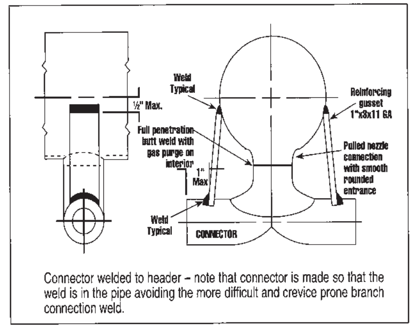


Figure 7 Transition with supporting gussetts, preventing corrosion due to vibration.

Pickling

Pickling is important to the successful performance of stainless steel WWTP piping. It ensures good corrosion resistance for aeration piping handling aeration basin sludges. Pickling is effective in removing heat tint scale, embedded iron and other pit initiating defects from the metal surfaces. Although most shops take care to minimize contact with carbon steel layout tables, platens, lifting chain, iron can still become embedded in the surface. Also, during cutting and welding, the adjacent metal is heated into a range where heavy brown or black oxide films (heat tint scale) form. Fabricators have a choice; they can ship as fabricated material and hope that customers may not object to staining or streaking from iron and other surface contamination arising from fabrication, or they can pickle and restore the surface to its most corrosion resistant condition. This can be done in acid vats or by the application of pastes and mild acid solutions to the contaminated areas, followed by a thorough neutralizing wash to remove the excess acid and pastes from the metal surfaces.

In aqueous environments where stainless steel has been selected and used for its corrosion resistance, a recent study undertaken by the University of Tennessee (9), supports the need to remove heat tint scale. *Figure 8* shows the polarization curves for as-welded Type 304L (with heat tint) and as-welded and pickled Type 304L (heat scale removed). The curve for the pickled condition, with heat scale removed, shows the normal passive (protective) behaviour associated with the austenitic stainless steel materials. The vertical section of the polarization curve defines the wide passive range characteristic of stainless steels. The lack of a similar passive range for the heat affected zone (HAZ) of as-welded samples, with heat tint present, indicates that localized corrosion is likely in aggressive environments.

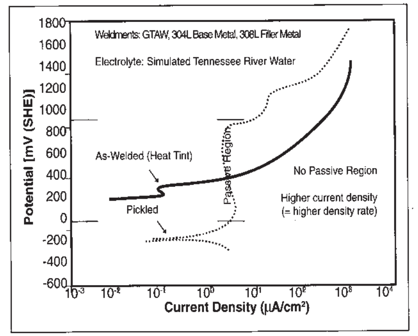


Figure 8 Polarization data showing effects of heat tint on corrosion resistance.

Cost Comparisons

Stainless steels offer a very cost effective approach for the design of light weight components and piping systems. Although the initial capital costs may be greater than for other material systems, stainless steel provides long term durability, lower overall maintenance costs and cost savings over the long term. In a European case study (10) undertaken by the European Stainless Steel Development and Information Group (EURO INOX) on an Italian WWTP, life cycle costs for stainless steel over carbon steel showed break-even after just 10 years of operation, despite the initial installation cost being approximately 25% more expensive for the stainless steel construction. This analysis includes the cost of capital, maintenance and repair and only considered a conservative estimate of 10% weight savings when designing with stainless steel. Stainless steel equipment included mechanical screens, travelling bridges and handrail assemblies, where galvanized steel is often used.

Conclusions

Types 304L and 316L stainless steel have been used extensively and very successfully for piping and a wide variety of other applications in waste water treatment plants. The higher design properties for stainless steel and its very low corrosion rates allow for lighter weight construction. Good housekeeping practices in-plant further enhance the excellent performance offered by these materials.

1. The ASTM specifications A312 and A778 are generally adequate for the procurement of pipe, provided that heat tint oxide scale removal is specified when ordering to ASTM A778.
2. In house specifications must be developed for circumferential butt welds, as these are not covered by ASTM specifications. These should include requirements for full penetration, rather than "commercial quality" welds.
3. Designing full penetration joints with smooth design contours and smooth weld bead profiles, rather than using fillet welds at branch connections, will optimize performance against vibration.
4. For waters where chlorides exceed 200 ppm (mg/l) or where residual chlorine exceeds 2 ppm, Type 316L is preferred to 304L.
5. For sludge service, maintaining flows above 2 ft/sec and avoiding recessed and creviced areas that are sites for sludge accumulation is essential for best performance.
6. Stainless steel 304L and 316L have been used for aeration, digester gas and sludge transfer piping in 1600 municipal waste water treatment plants built in the US since the late 1960's.

Acknowledgement

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STAINLESS STEEL FOR POTABLE WATER TREATMENT PLANTS (PWTP)

Stainless Steel for

Potable Water Treatment Plants (PWTP)

by RE Avery, S. Lamb, C.A. Powell and A.H. Tuthill

Grade Selection

Type 304L, the principal piping material used in PWTPs, has adequate corrosion resistance for most conditions, provided the surface is maintained clean and free of defects.

Type 316L is a more conservative choice and has improved corrosion resistance in the presence of sediment and other deposits when higher levels of residual chlorine exist.

Procurement

- Procure pipe to ASTM A778 or A312 to ensure proper quality for PWTPs.
- Specify "L" grades Type 304L or 316L. Dual certification grades are acceptable.

Piping Design

- Slope horizontal lines so they drain completely.
- Avoid dead legs and sections that cannot be drained during shutdown or stand-by.
- Provide inspection and wash-out ports on horizontal runs to allow flushing of sediment.
- Use Ni-Cr-Mo alloys, 6% Mo stainless steels, or cement-lined steel or ductile cast iron pipe in the section immediately downstream of chlorine or potassium permanganate injection.
- Design for the maximum flow rate consistent with pressure drop to reduce sediment deposition.
- Take advantage of the high C valve (low friction) for stainless steel.

Pipe Fabrication

- Require a welding procedure specification from the fabricator and require that only qualified welders be used.
- Specify required weld quality standards.
- Minimize or prohibit field welding of circumferential butt welds.
- In raw water sections, prevent or remove heat tint oxide on welds as described in the text.

Start-Up and Operation

- Drain promptly and completely after hydrostatic testing or during shutdowns. Circulate at least weekly if the system must be left full.
- Dissolve calcium hypochlorite granules before introducing them into stainless steel piping for disinfection.

General

- When in doubt, design, fabricate, install, and operate in a manner which will keep stainless steel piping clean and in its most corrosion-resistant condition.

Introduction

Types 304L and 316L welded stainless steel piping has been successfully used in over 100 PWTPs and related potable water applications in North America. Table I shows the common name, the UNS number, the British, German, Swedish, and EURONORM designations, with nominal compositions for the wrought alloys. The principal reason to use stainless steels is its outstanding resistance to contaminate potable water with metal ions. Stainless steel has been used since 1965 for the large, central-control, gravity filter in water treatment plants with good performance in over 75 installations. (1) Figure 1 illustrates two typical central-control units. Types 304 and 316 have been used with equal success in the fabrication of non welded components such as pump shafts and valve stems.

Stainless steels have given excellent performance in transporting potable water from Middle East desalination plants, potable water distribution systems in Tokyo, Korea, and New York City, and in over 100 North American domestic potable water treatment plants. Figure 2 illustrates a New York City pumping station gallery of laterals in the distribution hub serving potable water for Manhattan. The excellent performance offered by stainless steel depends on factors different from those that influence the performance of ductile cast iron (DCI), galvanized or coated steel, or copper alloys in potable waters. The few failures that have occurred are due to unfamiliarity with factors that affect the performance of stainless steels, as these factors are quite different from those of the older, more familiar materials. This summary and guide is intended to assist design engineers and operators in avoiding the problems that have occurred in PWTPs by ensuring the conditions required to support the optimum performance of stainless steels in these applications are met.

Recommended Applications for Various Stainless Steel Types

Types 304L or 316L are the standard grades of stainless steel used in potable water applications. Type 316L with 2-3% molybdenum is more resistant to pitting and crevice corrosion and is preferred over Type 304L for the more severe services. The low carbon "L" grades have a maximum of 0.03% carbon and should be used for welded fabrication rather than the regular grades which may contain up to 0.08% maximum carbon.

Where mechanical strength is important for design purposes, the slightly lower tensile and yield strengths of the "L" grades should be recognized. It is increasingly

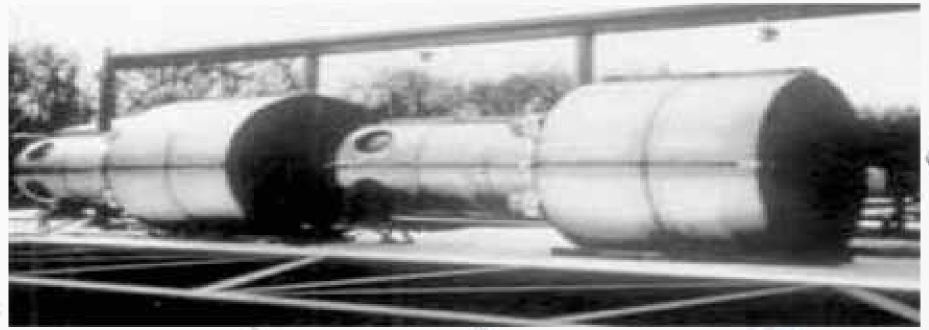

Figure 1 *Stainless steel central-control columns for a PWTP.*

Figure 2 *A gallery of laterals in the New York City pumping station. The laterals are made from cast stainless steel with 48 in. diameter wrought butterfly valves.*

Table I Alloy Identification and Compositions (%)

Common Name	UNS No.	EURONORM EN 10088	British BS*	German DIN*	Swedish SS*	Nominal Composition (%)				
						C	Cr	Ni	Mo	Fe
304	S30400	1.4301	304531	1.4301	2333	0.08	18.0	10.0	-	Bal
304L	S30403	1.4306	304511	1.4306	2352	0.03	18.0	10.0	-	Bal
316	S31600	1.4401	316531	1.4401	2347	0.08	17.0	12.0	2.0-3.0	Bal
316L	S31603	1.4404	316511	1.4404	2348	0.03	17.0	12.0	2.0-3.0	Bal

*Have been superseded by EURONORM

Table II Requirements for Typical Stainless Steel Pipe

Physical Characteristics, Tests, and Processes	Specifications		
Pipe Form	A312 Welded & Seamless	A778 Welded	AWWA C220 (1) Welded & Seamless
Size	1/4 - 30"	3-48"	4" or Larger
Wall Thickness	Sch. 5S - 80	0.062 - 0.5"	(1)
Solution Anneal	Required	Not Required	(1)
Mechanical Test	Tension & Face Bend	Transverse Tension & Guided Bend	(1)
Hydrostatic Test	Required	Optional	(1)
Filler Metal Addition	None Allowed	Matching	(1)
Surface Scale Removal	Required	Required	(1)
Associated Fitting Specification	ASTM A403	ASTM A774	

(1) AWWA C220 allows use of either ASTM A312 or A778. See the ASTM specification for particular requirements.

common to encounter dual certified Type 304/304L and Type 316/316L stainless steel in warehouse stock. Dual certification means that it meets the 0.03% carbon maximum requirement for the "L" grades and also meets the higher mechanical properties of the regular grades.

Materials

Pipe and fittings are usually specified to one of the material specifications in Table ll. Important provisions of the piping specifications are summarized.

Corrosion Behavior of Stainless Steel in Potable Water

Stainless steel performs best in clean, flowing water i.e., flow rates greater than 1.5 to 2 ft/s (0.5 to 0.6 m/s). In raw water, the suggested minimum design flow is 3 ft/s (1 m/s) to reduce sediment deposition.

High velocities and turbulence which limit the performance of materials such as ductile cast iron, carbon steel, and copper alloys are beneficial to the performance of stainless steel. Stainless steel offers excellent erosion/ corrosion resistance to handle turbulent flows. Reference conditions for potable water are shown in Table III.

Table III Velocity/Flow for Potable Water Systems Velocity - Avoid stagnant conditions

- Up to 100 ft/s (30 m/s) - OK
- > 3 ft/s (1 m/s) preferred for raw water with sediment
- 1.5 to 2 ft/s (0.5 to 0.6 m/s) for finished water Flow
- Reduces opportunity for bacteria and slime to form growth sites
- Reduces the possibility for microbiologically influenced corrosion

Because of its very low corrosion rate, stainless steel does not require the corrosion allowances used for ductile cast iron and carbon steel. Corrosion, when it occurs, is usually localized in crevice areas. There are two types of crevices:

- Man-made, originating from design or construction
- Natural, occurring in crevices formed by sediment or deposits.

A typical and very damaging man-made crevice is that formed at the root of incomplete penetration welds. Weld root crevices can trap sediment and allow chlorides to concentrate to several times the concentration in the bulk water increasing the likelihood of under-deposit crevice corrosion.

Procurement specifications should require full penetration welds with smooth ID contour. Other man-made crevices such as those at flange faces under gaskets, pressed fittings, and mechanical joints pose few problems in low chloride potable waters.

Naturally occurring crevices from sediment can be reduced by high flow rates. When design or operating conditions are such that deposits may occur, the best practice is to provide periodic flushing with a high pressure water stream. The design should provide the necessary flushing ports.

A black Fe-Mn deposit forms on the pipe wall when raw waters are treated for the removal of iron or manganese with oxidants such as chlorine or potassium permanganate.

The Fe-Mn deposits are normally benign to Type 304L stainless steel, but have contributed to under-deposit crevice corrosion in the presence of heat tint oxide from welding. The removal of heat tint oxide is discussed in the paragraph entitled Fabrication of Piping Systems.

Guidelines for the injection of chlorine are discussed in the paragraph entitled Effects of Oxidizers.

Effect of Chlorides

The chloride level of the water is an important factor in determining the resistance of stainless steel to crevice corrosion. (2) The chloride level can be readily measured and used by engineers as a first indicator for the likelihood of crevice corrosion. Beware that there are other important interacting factors that may have a major role, such as the presence of strong oxidants, crevice geometry, and pH.

Laboratory trials supported by service experience suggest that for the majority of natural, raw, and potable water with pH in the range 6.5 to 8:

- Crevice corrosion of 304/304L is rare below about 200 mg/l of chlorides
- Crevice corrosion of 316/316L is rare below about 1000 mg/l of chlorides.

A much more conservative approach, as may be required when other conditions are particularly unfavorable, is to use 304/304L when chlorides are below about 50 mg/l and 316/316L when chlorides are below about 250 mg/l.

When the chloride level is over 1000 mg/l, a higher molybdenum or duplex stainless steel may be required, and it is advisable to consult an expert.

Waters in PWTPs normally contain oxygen. In fully de-aerated waters, much higher chloride levels can be tolerated. Stainless steels are generally resistant to crevice corrosion in totally de-aerated waters, including sea water which contains about 18,000 mg/l chlorides.

Effect of Oxidizers

Chlorine, ozone and potassium permanganate are common oxidizers used in PWTPs for various purposes.

(3) Figure 3 shows 36 inch diameter, 30 ft. high, stainless steel mixing towers that are typically used for both chlorine and ozone mixing. In this installation, chlorine concentration is maintained below 4 mg/l and, typically, at 2 mg/l. Oxidant additions, up to some limiting concentration, can be beneficial to stainless steel in preventing microbiologically influenced corrosion (MIC).

The effect of chlorine on the corrosion of stainless steel is shown in Table IV. The data were gathered from corrosion test spools that were exposed in four locations.

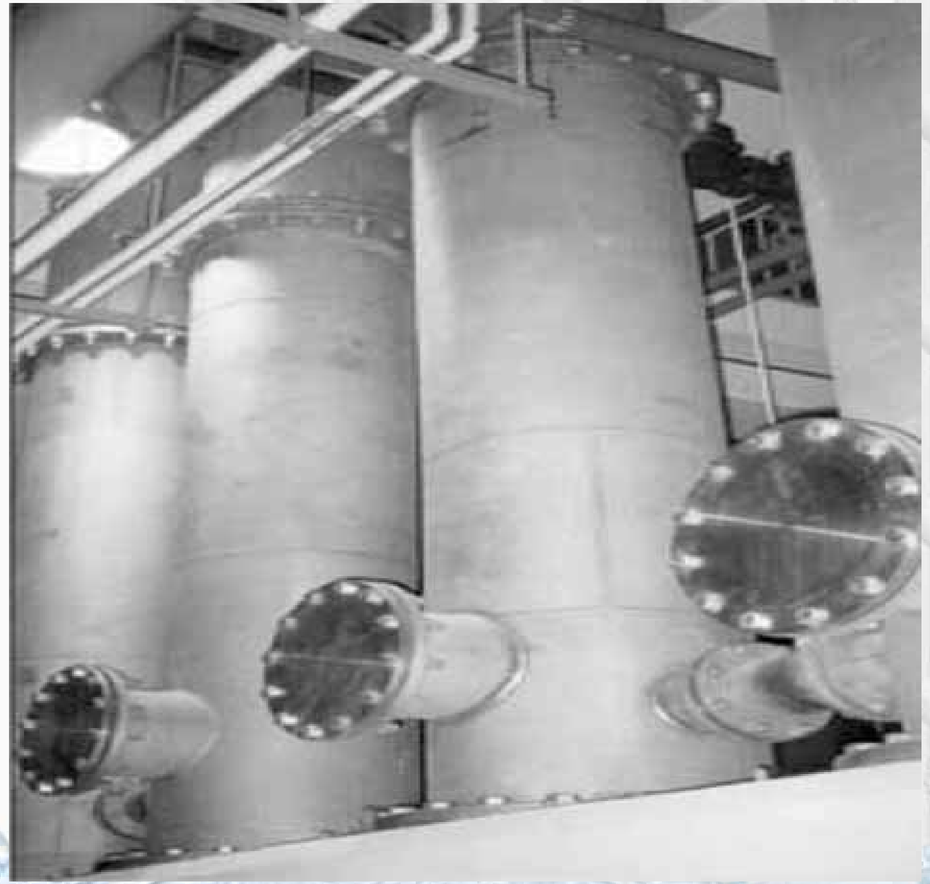

Figure 3 *Typical stainless steel chlorine/ozone mixing towers*

Table IV Effect of Chlorine on Corrosion of Stainless Steel

Chlorine Residual	Maximum Depth of Attack mils (mm)			
	Type 304		Type 316	
mg/l	Base Plate	Crevice	Base Plate	Crevice
0 (1)	0	0	0	0
0.8 – 1. (1)	0	0	0	0
2.0 (1)	0	0	0	0
3 – 5 (2)	<1 (0.03)	4-14(0.1 - 0.4)	0	1-5 (0.03 - 0.1)

(1) Water contained 23 mg/l of chlorides

(2) Water contained 790 mg/l of chlorides

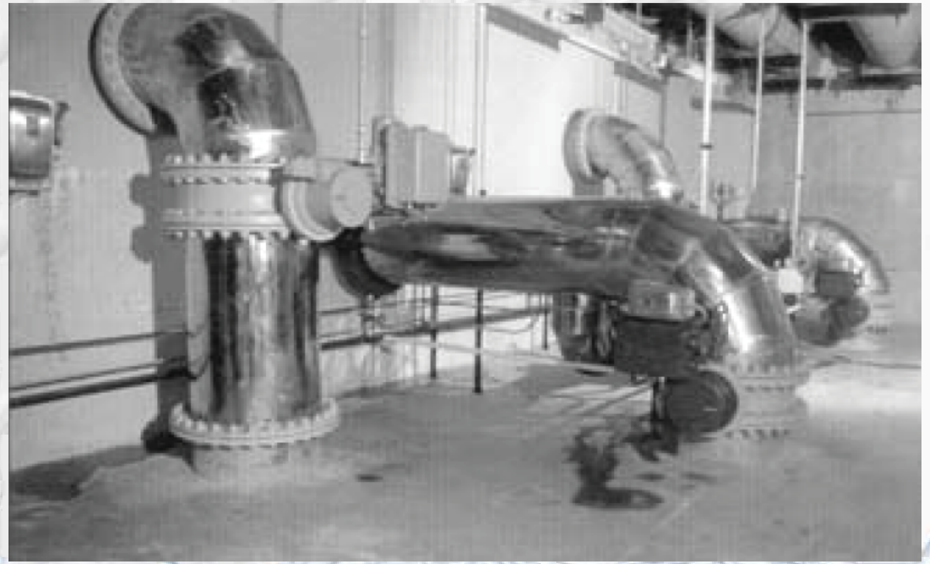

Figure 4 *A section of stainless steel piping in the PWTP in Taunton, Massachusetts where cost savings were realized by using lighter weight stainless steel instead of ductile cast iron.*

In each case a baseline exposure in unchlorinated water was made for comparison.

These data indicate that in the 3-5 mg/l residual chlorine range, Type 304L becomes vulnerable to crevice corrosion. Type 316L can be expected to be more resistant to crevice corrosion in the 3-5 mg/l range of residual chlorine. Since residual chlorine may be up to 1.8 mg/l in finished water at the PWTP in order to meet the 0.2 mg/l minimum at point of use, Type 304L is an excellent material to use for finished water and distribution systems.

Stainless steel can tolerate considerably higher levels of chlorine for short time periods. The AWWA C653 disinfection treatment of 25 mg/l of chlorine for 24 hours is standard practice and there have been no reported problems.

The section immediately downstream of chlorine injection requires special attention. The critical section length is 10 times the diameter of the pipe. The concentration of chlorine injected is higher than stainless steel normally tolerates unless there is extremely rapid mixing.

Alternate materials for this section are the Ni-Cr-Mo alloys, the 6% Mo super austenitic stainless steels and the 25% chromium super duplex stainless steels.

Chlorine, but not ozone, has another important effect. In the moist vapors just above the water line, chlorine concentrations may reach concentrations that stain and even pit Types 304, 304L, 316 and 316L stainless steel.

This is more of a cosmetic problem than structural. One water district has been using stainless steel structurals in clearwells since the late 1950s and has not encountered the need for replacements. With long exposure, the staining is followed by shallow pitting over the entire exposed surface.

Vapor-side staining and pitting attack have been reported in several PWTPs where pipe galleries were not well ventilated near the Chlorine injection area.

Microbiologically Influenced Corrosion (MIC)

Potable waters are disinfected to kill pathogens and control bacteria. However, there are instances where MIC probably occured in both raw water and process lines in PWTPs, especially where water has been allowed to stand and stagnate overtime. (4)

- In at least three PWTPs, the hydrostatic test water was not promptly drained; the probable cause of MIC attack at the circumferential welds where the heat tint oxide was present. Longitudinal welds had been pickled and were resistant to MIC.
- One plant has also reported corrosion in a longitudinal weld of a horizontal run of stainless steel where finish water stood stagnant for long periods.

Stagnant water conditions can be avoided by draining promptly after hydrostatic testing, provided horizontal runs have been sloped for drainage. Dead legs should be eliminated through design. Sections that must be placed on stand-by can either be drained or the water can be circulated periodically. There is evidence that it takes at least 30 days for MIC to develop and initiate corrosion. Consequently, raw water systems should be circulated at least weekly to avoid stagnant conditions which could contribute to MIC in the weld heat tint oxide area.

Design

The use of stainless steel piping rather than ductile cast iron can yield the important advantages of thinner wall, lower weight, and fewer field connections - all of which reduce installation labor. Figure 4 shows a section of the Taunton, Massachusetts PWTP where the use of stainless steel piping rather than the heavier DCI saved entitled Effects of Oxidizers.

$50,000 (US). A summary of design guidelines is shown in Table V.

Fabrication of Piping Systems

Quality workmanship during the fabrication, erection, and field welding is essential for optimum service. Utilizing reputable organizations with experience in stainless steel fabrication will greatly minimize the likelihood of corrosion problems.

All PWTP circumferential pipe welds that are welded only from the OD should be made using the gas tungsten arc welding (GTAW) or TIG process for the root pass along with an internal inert gas purge to exclude oxygen in the weld root area.

Heat tint oxide in the weld heat-affected zone is one of the major contributors to under-deposit corrosion and microbiologically influenced corrosion in potable water treatment systems. The heat tint oxide can vary in color and thickness ranging from a thin, light, or

straw-colored oxide to a dark, (black) oxide of appreciable thickness. The heavier the oxide, the more likely that it will contribute to the initiation of corrosion.

Heat tint oxide alone will not initiate corrosion in potable water. An abnormal condition in the environment is also necessary. Stagnant water left in the system for 30 days or more has initiated MIC at welds with heat tint oxide.

The black Fe-Mn deposit that forms in the section between the point of chlorine or permanganate injection and the filters has also initiated localized corrosion at welds with heat tint oxide. Base metal and welds that were cleaned of heat tint oxide were resistant.

Practical actions to remove or eliminate weld heat tint oxide differ according to pipe size.

Table V Guidelines for the Design of Stainless Steel PWTP Piping Systems Mechanical Features
• Slope the horizontal lines so that they will completely drain, including the low points between supports.
• Provide access for inspection and flushing out of sediment, debris and deposits in the raw water piping.
• Use eccentric reducers where appropriate to facilitate draining. Velocity-Avoid stagnant conditions and dead legs.
• Normal good design flow rates minimize the opportunity for bacteria to build biomounds and initiate MIC.
• Minimum flow rates to reduce possible sediment accumulation and corrosion are: 3 ft/s (1 m/s) for raw water with sediment, 1.5-3 ft/s (0.5-0.6 m/s) for finished water where the sediment is less likely.

1. 24 in. diameter and larger pipe: Pipe sizes 24 in. and larger are accessible for internal conditioning. Remove heat tint oxide by pickling the interior weld surfaces, by grinding with an abrasive tool such as a rotating silicon carbide-impregnated fiber brush, or by electropolishing with a hand-held electropolishing probe.
2. 3 in. diameter and smaller pipe: Remove heat tint oxide by pickling the pipe assembly or by using mechanical joints. Alternately, assurance of heat-tint-free welds usually requires automatic orbital welding with very precisely machined joint preparations.
3. Pipe sizes greater than 3 in. and less than 24 in. diameter: The piping fabricator should be required to remove or prevent the formation of heat tint oxide using one of the following options best-suited for the particular assembly.

- Limit assembly length to accommodate pickling the unit or placing welds so they are accessible for internal grinding.
- Prevent any significant heat tint oxide formation through very precise weld joint preparation and careful internal purging procedures. Automatic orbital welds can be made free of heat tint. The fabricator should be required to demonstrate the ability to make heat-tint-free welds.
- Use mechanical connections on joints where heat tint oxide removal is not practical.

Other minimum fabrication requirements should include the following:

- Proof of acceptable welding procedure specifications for the work to be performed and verified welder performance qualifications. The engineer and/or customer should review and verify both. Suggested guides are ASME Section IX and AWS B2.1.
- Require full penetration welds, free of cracks, overlaps and cold laps.

- Limit misalignment for manual welds to 1/16 in. (1.6 mm) or half the wall thickness, whichever is less. Automatic orbital welding procedures are usually more restrictive on misalignment.

- Limit on weld reinforcement and concave root (11/16 in. [1.6 mm]), or to agreed-upon limits.

- Limit on undercut, e.g. 1/32 in. (0.8 mm) or 10% of base metal thickness, whichever is less.

- Provide for secure end closures and leave in place until final assembly.

- Provide for prompt and complete drainage of the piping systems after hydrostatic testing.

Post-Fabrication Cleaning

Embedded free iron on stainless steel surfaces causes rust marks to form and in some instances provides the sites for the initiation of corrosion. (5) Figure 5 shows the development of rust at a weld brushed with a carbon steel wire brush; only stainless steel wire brushes should be used.

Nitric acid and other "passivation" treatments described in ASTM A380 are not fully effective in removing iron and other surface defects. Pickling with nitric-hydrofluoric acid removes free iron and a thin surface layer of metal that may contain surface defects; the metal surface is then passive and in the most corrosion-resistant state. If a nitric-hydrofluoric acid pickle is not practical, the free iron can be removed mechanically. Acceptable methods include the use of medium to fine-grit abrasives such as clean flapper wheels, flexible disks, or blasting with clean abrasives such as glass beads, garnet, or walnut shells. Free iron and heat tint oxide can also be removed by a hand-held electropolishing probe.

The water wetting and drying procedure described in ASTM A380 is a very effective test to check for the removal of free iron. The procedure calls for wetting the surface with distilled or deionized water or fresh water followed by drying.

After the wet-dry cycles, the surface should show no evidence of rust stains or other corrosion products. The ferroxyl test for free iron described in A380 is even more sensitive but may not be acceptable for use in potable water systems.

Operations and Maintenance

Failure to drain promptly after hydrostatic testing or allowing water to remain stagnant in piping or tanks for extended periods of time has led to MIC. In stagnant water, bacteria have an opportunity to develop biomounds and multiply, leading in some instances to MIC at welds where there is heat tint oxide. Over 90% of the reported instances of MIC occur in the vicinity of welds. There are occasional reports of MIC on bare metal away from welds, but these occurrences seem to be in severe MIC environments. The following actions avoid MIC even when heat tint oxide is present.

- Drain promptly and blow dry after hydrostatic testing or when the system is placed in extended standby. Alternately, circulate water if draining is not possible.

- Place in service within a few days after hydrostatic testing and provide for prompt draining should the system be placed in standby at some future date.

- Slope horizontal runs sufficiently so they will drain without leaving water between support points. Other guides for the operation and maintenance of stainless steel piping systems includes the following practices:

- Establish a schedule to flush out sediment and debris on horizontal runs of raw water piping.

- During downtime, drain completely and dry or, alternately, circulate water for one hour daily.

- For the initial disinfecting treatment, dissolve calcium hypochlorite granules before introducing them into or onto the surface of stainless steel piping. Calcium hypochlorite granules dissolve slowly and have created a severe micropitting environment when resting on stainless steel.

- Provide proper ventilation to clear chlorine from all enclosed spaces.

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Source : Nickel Institute

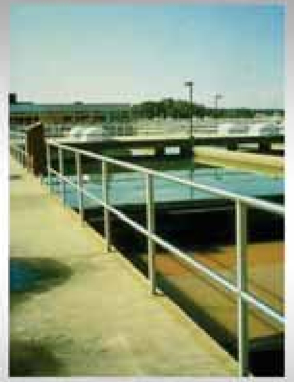
STAINLESS STEEL IN WATER TREATMENT AND DISTRIBUTION - AN OVERVIEW

Stainless Steel in Water Treatment and Distribution

David Jordan
Nickel Institute

In the atmosphere..

- Rural areas-304L
- Coastal areas-316L
- Occasional wash down to remove deposits



Areas where chlorine vapours collect:
- Wash down or vent
- Higher grade steel

Benefits of Stainless Steels in Potable Water Treatment

- Tolerate wide range of water chemistries
- Water treatment unnecessary except for biocide
- Coatings not required
- Withstand high flow rates
- Excellent resistance to aeration
- Strong, yet ductile
- Can use thinner light-weight sections
- Easily welded and readily fabricated
- Recyclable

Lake Como Potable Water Plant, Italy

Plant fixtures

Ladders and fixings

Walkways

Water Treatment and Distribution

Property	Treatment Plant	Distribution System
Turbidity	Particulates	Clean
pH	6-8.5	7-8.5
Oxygen	Low to saturated	Saturated
Oxidants	O_3, Cl_2, ClO_2, $KMnO_4$	Low oxidant residual
Fe+Mn	Precipitated	Very low
Chemicals	e.g. $FeSO_4$, $FeCl_3$	None

Slide Gates

316 stainless steel

Grade selection guidelines for immersed conditions

Chloride content of the water is most important parameter

Practical experience and tests show crevice corrosion is unlikely at pH > 6 and ambient temperature when:

Chloride level	Suitable grades
<200 ppm	304L
< 1000 ppm	316L
<3600 ppm	duplex 2205,
>3600 ppm and seawater	6% Mo super austenitic, super duplex

316Ti Pipework in Water Works, Germany

Lightweight welded and flanged construction

Flanged joints:

Ensure gaskets are:

- Non-porous
- Chloride-free
- Do not contain graphite

Welded joints:

- Cleanliness important
- Gas-shielded processes good
- Ensure full weld penetration
- Inert gas purge in the bore
- Remove external heat tint

Flow rates

- Preferred minimum velocities to avoid sediment build up:
  - Clean water > 0.5m/s
  - Dirtier waters >1m/s
- Avoid dead legs
- Slope pipes
- Flow rates up to 40m/s

Piping gallery in water treatment plant, New Zealand

Granulated Activated Carbon Tanks

Italy

316 stainless steel water softening reactor

Pumping station pipework, New York

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

Life Cycle Cost =

(whole of life cost)

Initial Installed Costs

Materials	Fabrication	Installation

+

Costs over the life of the structure

Maintenance	Replacement	Disruption

Life Cycle Cost – Lightweight River Bridges

- Carry potable water and pedestrians
- Spans up to 632 m
- 85% 304 / 10% 316
  Coastal –some duplex
- No repainting
- 40% cheaper over 30 years
- First one built: 1983
- Max. pipe diameter: 0.8 m
- Max. weight of stainless steel: 45 t
- ~3000 bridges (10,000 t stainless steel)

Japan

Stainless Steel for Refurbishing Water Mains

Padua, Italy

6m lengths of 304 stainless steel pipe inserted into an old water main from an open pit under a narrow road.

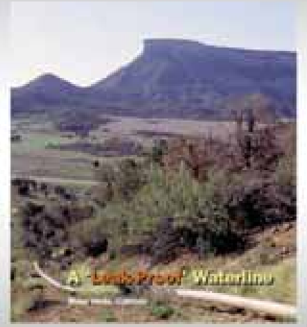
Max. push length – 1 km

Cost saving v. excavation e.g. 40%

Distribution pipe

Vancouver, Canada

Directional drilling to install water pipe



11 km of 6-in pipe

Mesa Verde National Park, USA

Soils

Corrosion unlikely if :

- pH>4.5
- Resistivity >2000 ohm.cm
- Good drainage and clean backfill

If risk of corrosion:

- Upgrade alloy
- Wrap, encasement or cathodic protection

Grade Selection for Soils

Grade	Soil Conditions
304L	Chloride < 500 ppm
316L	Resistivity > 1000 ohm.cm pH > 4.5
316L	Chloride < 1500 ppm Resistivity > 1000 ohm.cm pH > 4.5
Super duplex Super austenitic	Chloride < 6000 ppm Resistivity > 500 ohm.cm pH > 4.5

Stainless Steel Plumbing

Stainless steel piping systems have been used for many years to handle waters in the chemical, pollution control, pharmaceutical and food industries

They are now being increasingly used to distribute potable water in buildings

Couplings and clamps

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

For best performance of stainless steel pipework:

- Horizontal runs should have a fall for drainage
- Design out dead legs
- Use Type 304 < 200 ppm chlorides
  Use Type 316 < 1000 ppm chlorides
- Use low-chloride insulation
- (< 0.05% water-soluble chloride ions)
- If insulation will be exposed to wet chlorides, eg. coastal conditions, provide a protective layer between the insulation and the stainless steel pipe, eg. aluminium foil
- Use low-chloride sealants and anti-galling lubricants
- If pipework is hydrotested, drain promptly and completely after testing

Plumbing in high-rise building

Prestige buildings:

Shaanxi Telecommunications Centre, Xian, China

150 m high, 38 stories

Type 304 stainless steel tube is used for hot and cold water supply throughout the building

Large diameter Type 304L water distribution pipes at the top of a high rise building in Tokyo

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

Fittings

A variety of stainless steel fittings are available. Copper alloy fittings can also be used (normally dezincification-resistant brass or gun metal):

- Capillary fittings for silver solder and adhesive (do not use chloride-based soldering fluxes)
- Compression fittings
- Pressfit system applied using an electro-mechanical tool to crimp around a polymer sealing ring

With flanged joints, ensure gaskets are:
- Non-porous
- Chloride-free
- Do not contain graphite

Hospital in UK (Scotland) where copper tubing, which suffered pitting by soft water, was replaced with type 316 stainless steel Pressfit system, and trials carried out

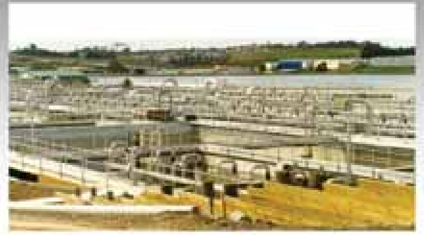
Scottish Hospital, UK

Stainless steel piping in the corridor ceiling. Copper alloy compression fittings were used – dezincification-resistant brass for small sizes; gunmetal for large sizes

Stainless Steel in Waste Water Treatment Plants

Waste Water Treatment Plant - Applications

Screens
Grit removers
Scrapers
Slide gates
Aeration piping
Pumps and valves
Sludge transfer piping
Tanks
Digester gas piping
Weirs
Ozone generators and piping
Ultraviolet equipment
Chemical treatment lines
Ducting
Backwash systems
Distributors



Waste Water Treatment Plant, Auckland, NZ

Immersed Conditions - Which stainless....?

- Grade primarily defined by chloride level of effluent- similar to water treatment guidelines

Gas transfer piping at waste water treatment plant in New Zealand

Screens

Settlement Tank, New Zealand

Ex L. Boulton NewZealand

Multi-Rake Bar Screens

ex Hans Huber , Germany

Micro-strainers

ex Hans Huber, Germany

Used for the removal of finely suspended solids from secondary clarifier effluent

Piping: External Environment

- Open atmosphere
- Moist environment with hydrogen sulphide
- Activated sludge with chlorides, sulphates and other chemicals

Removal of Grit and Screenings

Piping: Internal Environments

- Warm air and moisture
- Moist digester gases
- Sludge with chlorides, sulphates, hydrogen sulphide and other gases

BAFF reactor cell pipework.
(Manifolds 2205. Lower inlet pipes and unconnected recycle lines 316L)

Hydrogen sulphide….

- Moist hydrogen sulphide generally has minimal effect on stainless steels
- In closed systems with moist hydrogen sulphide, chlorides and high temperatures, or where sulphurous acid formed, use -
  2205 Duplex
  or 904L (25Ni-20Cr-4.5Mo-Cu)

Transfer piping

Germany

Italy

Aeration basin, USA

Type 304 stainless steel

Piping system below sand filter basins - Sewage treatment plant in Sweden

Ex. Outokumpu

ISDA STAINLESS STEEL

Thickened sludge 30% DS discharge line 60 bar rating

UK

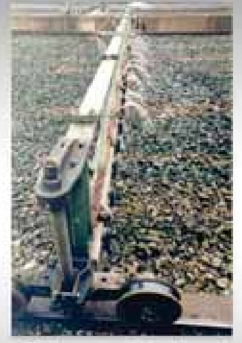
Pipe Insulation

- Need to avoid leaching of chlorides on to metal surfaces
- Less than 0.05% chlorides preferred in insulation materials
- Less than 6mg/kg water-soluble chlorides in mineral wool

Flow rates

- Preferred velocities to avoid sediment build-up:
  - Clean water > 0.5 m/s
  - Dirtier waters > 1 m/s
  - Wet sludges > 0.6m/s
- Avoid dead legs
- Provide access points for flushing out
- Slope pipes

Distributor design change , UK



Old coated steel unit

New unit: 304L Frame and 316L chassis

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

Housing Estate Sewer Pipe – Auckland, NZ

60 m long, 300 mm dia, x 3 mm w/t spiral welded 316L pipe 304L flanges

Stainless steel pipework in package plant

Ease of Assembly

Skid-mounted stainless steel pipework assembly

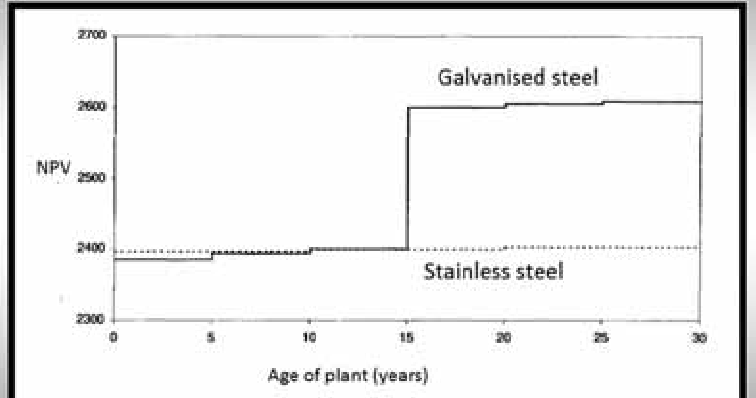
Membrane Boxes

ex Centrolnox, Milan

ISDA STAINLESS STEEL

Digester Dome-Italy

Economic benefit - Life Cycle Costing (LCC)



Odour Removal Ductwork

Odour Removal Unit

UK

Ultraviolet Treatment of Wastewater

The upper structure is in 304L and the wetted surfaces are 316L

Ex Trojan, USA

STAINLESS STEEL IN DESALINATION THAMES GATEWAY WATER TREATMENT WORKS

Stainless Steel in Desalination

Thames Gateway Water Treatment Works

The first water desalination plant in the UK, the Thames Gateway Water Treatment Works in East London, opens in 2010. It will treat water from the brackish waters of the River Thames, producing up to 150 million litres of clean, fresh, drinking water each day during times of drought or extended periods of low rainfall, or to maintain supplies in the event of an incident at other water treatment facilities. Within the plant, saline river water passes through lamella clarifiers to remove solid particles. The clarifiers are large, open tanks containing a coarse filter media that is supported by a grillage of 78 stainless steel I-beams.

Material Selection

Drinking Water Inspectorate (DWI) approval is needed for all materials that come into contact with drinking water. The main beams were initially specified to be carbon steel with an epoxy coating. However, there was a high risk of damage to the epoxy coating by follow-on operations and maintenance, which would have resulted in rusting and subsequent damage to the £7 million desalination membranes. This concern led to duplex stainless steel grade 1.4462 (S32205) being specified instead. This grade is DWI approved, requires little maintenance and is durable in brackish water without any applied coating (Table 1). The higher material cost of stainless steel is offset against the reduced risk of damage, low maintenance requirements and greater assurance of water quality throughout the plant's design life of at least 60 years.

Table 1: DWI approved grades of stainless steel in various water types at temperatures encountered in drinking water supply and treatment [1]

Water type	Chloride level (ppm)	Specification
Pure water		1.4301 (S30400)
Supply water	< 350	1.4301 (S30400) [1] 1.4401 (S31600)
Fresh water or ground water	< 1000	1.4301 (S30400) [1] 1.4401 (S31600) 1.4462 (S32205) Super austenitic, Super duplex
Brackish water	10,000 – 15,000	1.4462 (S32205) [2] Super austenitic, Super duplex
Sea water	15,000 – 26,000	Super austenitic, Super duplex

1) Only up to 200 ppm

2) In estuary or tidal waters, 1.4462 is only suitable up to 3,600 ppm

Figure 1: Desalination plant

Figure 2: Main beams

Design

Beams

The lamella clarifiers are divided into three cells, which are split in two halves. Each half is supported by 13 stainless steel beams of 17.5 m span, with supporting steel bracing at approximately 3 m intervals. The grid of beams carries a load of 2.5 kN/m2 during full working conditions (Figures 3 and 4).

Design of the main beams was completed according to the Design manual for structural stainless steel [2] and BS 5950-1 [3]. Guidance in the Operational guidelines and code of practice for stainless steel products in drinking water supply was also followed [1].

Directly replicating the carbon steel beam design in duplex stainless steel would have led to a 74 % cost increase. Therefore, a number of measures were undertaken to reduce the cost.

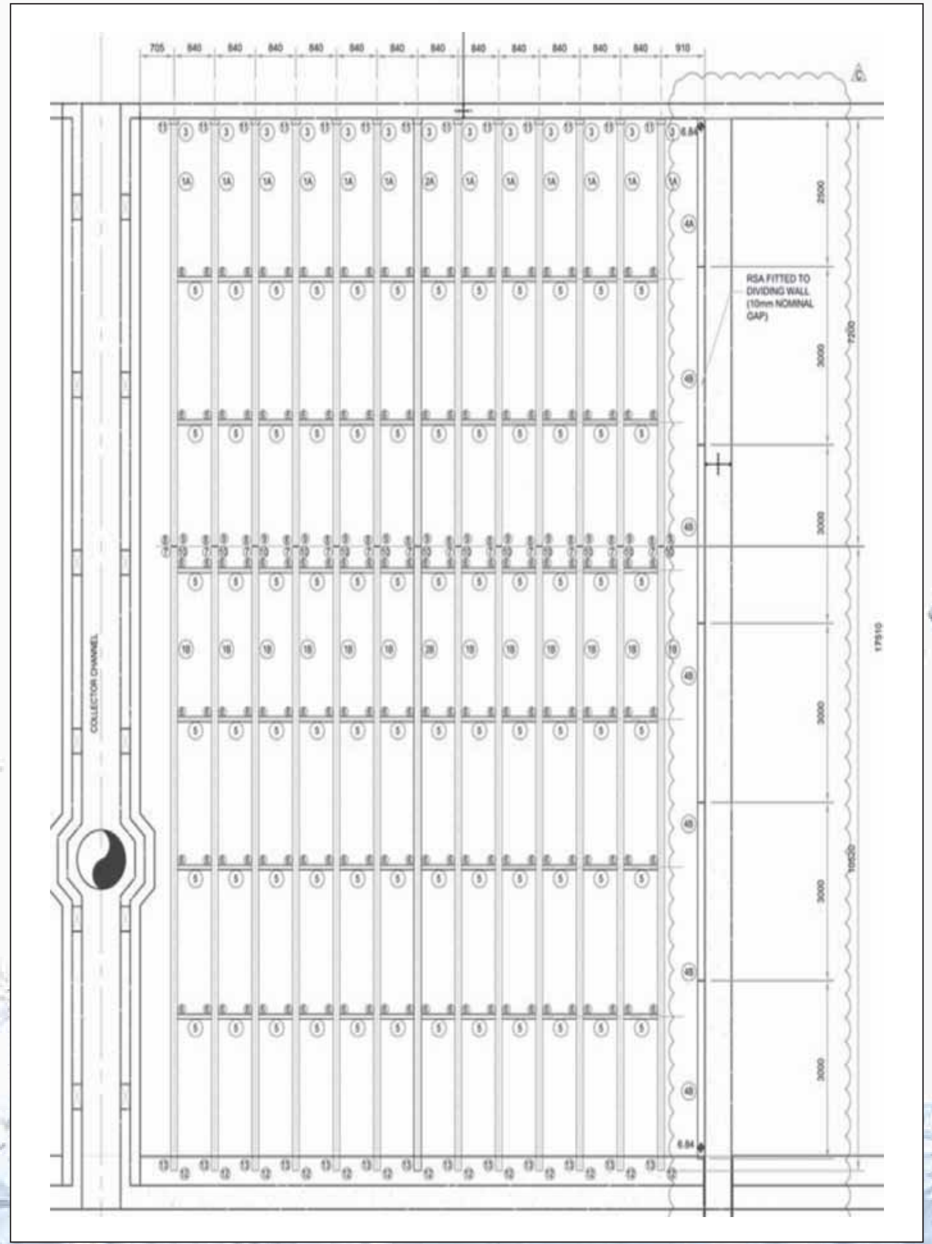


Figure 3: Plan drawing of lamella steelwork

Figure 4: Lamella clarification filter

Cost Savings

Design and fabrication:

- The profiles were designed using the superior strength properties of grade 1.4462 (minimum design strength of 460 N/mm2).
- A web depth of 500 mm was selected, to be fabricated from plate material produced in 2 m sheets, hence minimising offcut wastage.
- The flange thicknesses and dimensions were sized to optimise the section modulus.

As a result, the total weight of the stainless steel beams was reduced from 140 tonnes to 75 tonnes, allowing considerable cost savings. The most common profile for the stainless steel beams was a 512 mm x 132 mm I-beam with web thickness of 6 mm and flange thickness of 13 mm.

Transportation:

- As delivery costs from fabrication yard to site were extremely high for the 17.5 m span beams, the sections were designed to include a splice detail to shorten the lengths for delivery. The splices were placed approximately at 1/3 span, creating 2 lengths of beams: 10.52 m and 7.2 m. The beams were connected on site using duplex stainless steel spacers, angles and plate elements. (Figure 6).

Supporting steelwork

The ends of the main beams were supported from the concrete wall using 200 mm x 100 mm x 200 mm cleats connected into 200 mm x 150 mm x 450 mm angle brackets, secured by mechanical anchor fixings (Figure 5).

The beams were also braced transversely by 80 mm x 80 mm x 8 mm angles spanning 834 mm in between the beams, at 3 m intervals, to form a grid formation. All the steelwork supporting the main beams was fabricated in duplex stainless steel, hence avoiding any bimetallic corrosion issues.

Figure 5: Connection of beams to concrete wall

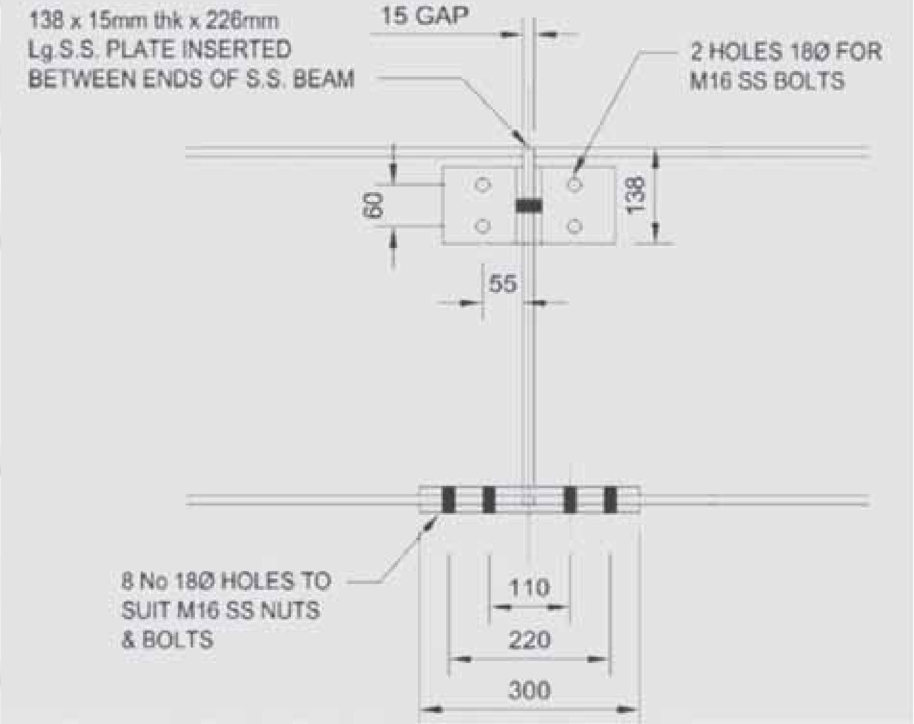


Figure 6: Splice connection

Fabrication

The steelwork package comprised 78 duplex steel beams with supporting steel; the beams were fabricated from 156 beam sections and spliced together using 624 splice components, 114 angle brackets and 1782 duplex grade bolts, all in grade 1.4462.

The sections were cut, profiled, drilled as necessary and welded with a specified surface finish of 1D in accordance with EN 10088-3 [4]. (This is equivalent to a No. 1 finish to ASTM A480.) All beam and angle sections were formed by laser welding with full 'hybrid fusion welding'. After welding, the surfaces were pickled and passivated to remove any contaminants and produce a standard non aesthetic but corrosion-resistant finish.

Figure 7: Completed lamella steelwork

Installation

The beams were assembled in pairs and installed using a tower crane (Figure 8). During erection, the stainless steel elements were isolated at all points of contact from carbon steel chains, plates and bolts, to prevent contamination of the surface, which might lead to subsequent corrosion. For this reason, temporary stainless steel bolts were used during erection. However, whenever surfaces are under load and in relative motion, galling may result from local adhesion and rupture of the surfaces; in some cases, weld bonding or seizure may result. Galling problems with stainless steel bolts can be avoided by using dissimilar grades of stainless steel for the bolt-nut combination, by the use of anti-galling agents or by applying a hard surface coating to the bolt or nut.

Figure 8: Installation of a pair of main beams

Information for this case study was kindly provided by Interserve.

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[1] DWI Operational Guidelines and Code of Practice for Stainless Steel Products in Drinking Water Supply, 2002, BSSA

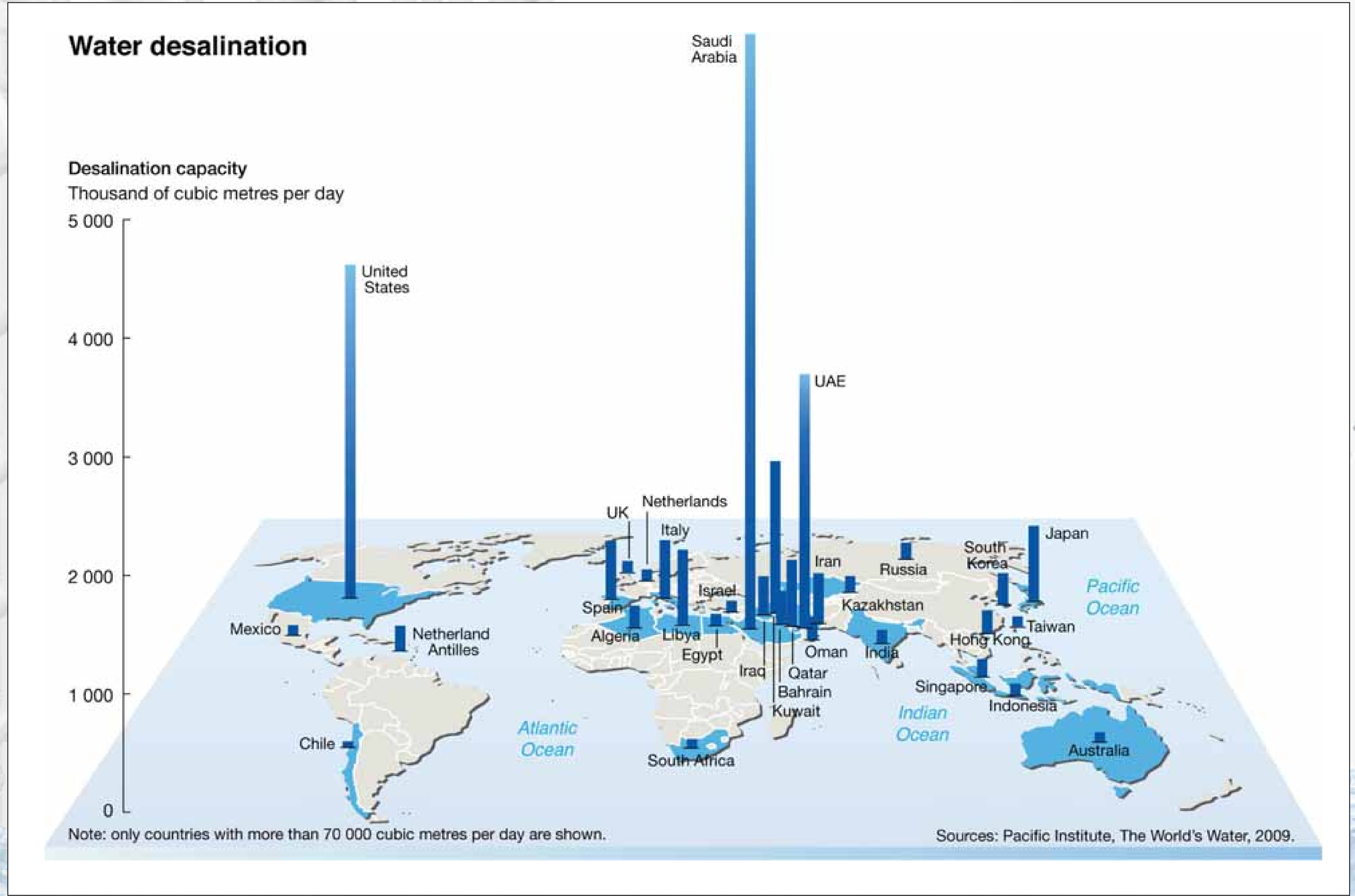
[2] Design manual for structural stainless steel (third edition), Building Series, Volume 3, Euro Inox and SCI, 2006

[3] BS 5950-1: 2000 Structural use of steelwork in building. Code of practice for design. Rolled and welded sections

[4] EN 10088-3: 2005 Stainless steels. Technical delivery conditions for semifinished products, bars, rods, wire, sections and bright products of corrosion resisting steels for general purposes

Online Information Centre for Stainless Steel in Construction: www.stainlessconstruction.com

Source : www.stainlessconstruction.com



HOW STAINLESS STEEL WATER PIPES CUT COSTS AND REDUCE WASTE

How Stainless Steel Water Pipes Cut Costs and Reduce Waste

It might take a few years, but stainless steel pipe could become as common in North American domestic water systems as it is currently in Japan or Germany. Penetration of stainless into the North American market is off to a good start with the completion of one such application at a high-profile venue in Detroit, Michigan.

The venue is a new, US$300-million stadium called Ford Field, which is being built by the Ford family, owners of the hometown "Lions" of the National Football League.

A total of 600 meters of S30403 stainless steel pipe—300 millimeters (mm) in diameter and

Incoming potable water is pumped through 500-mm-diameter, schedule 10 pipe, made of S30403 stainless steel.

with a wall thickness of 4.57 mm - has been suspended from the concrete ceiling around the entire stadium perimeter. The grooved ends of the pipe were connected using mechanical couplings and smaller-diameter copper pipes deliver potable water from the main stainless pipe to various washrooms and concession stands around the stadium.

The pipe was manufactured by Felker Brothers and distributed by Bertsch, aUSFlow Company. W.J.O'Neil Company (WJO), a mechanical contractor, won a US$25-million contract to fabricate and install all the plumbing, waste and heating systems for the stadium, which is scheduled to open in time for the 2002 football season.

The decision to use stainless was based almost entirely on economics, according to Robert Gazda, General Manager of WJO. Although material costs were some 20% higher than if galvanized carbon steel pipe has been used, significant savings in fabrication and installation were realized as a result of opting for stainless.

The excellent corrosion resistance of stainless steel allowed thinner wall thicknesses to be used than other competitive materials, resulting in several factors that helped to reduce installation costs. Considerable weight savings per metre of pipe were realized, as well a greater ease in the handling, lifting and installation of long sections of pipe. WJO was able to install sections up to six metres long.

For the operators of the sports facility, the main advantage of stainless steel is that the lines need to pipe had been used, more frequent flushing would have been required to remove the zinc corrosion products (zinc carbonate and sulphate) that inevitably develop. This means less labour will be required for flushing and less water will be wasted, an important consideration in a city where water supply costs have gone up by 30% in the past year.

Since stainless has never been used in a domestic water system in Michigan, no state engineering standard existed prior to this installation. It is not surprising, then that the City of Detroit put up some resistance. However, recent NiDI Water Workshop presentations is in the region in the fall of 2000, and experience gained from the use of stainless steel cold water piping at the Veterans Hospital in Detroit, where 500-mm-diameter stainless steel pipe was installed in 1993 under Federal standards, helped convince city officials to accept the use of stainless steel at Ford Field.

Reflecting on WJO's success in developing an economical way to fabricate and install the stainless pipe, Gazada says, "I'm sure there will be a whole lot more jobs after this one".

LIGHTWEIGHT STAINLESS STEEL construction permits easy and simple lifting of pipe into place, 5 metres off the floor. Two men easily connect 6-metre lengths of pipe using relatively simple equipment. In addition, there is no need to clean the ends of the grooved pipe. Stainless steel sub-assemblies and pre-fabricated and curved, mitered sections avoid the need for complex fittings and connections. Smaller diameter copper pipes deliver water to various washrooms and concession stands. Stainless steel piping has been used in Detroit's Veterans Administration Hospital since 1993. Incoming potable water is pumped through 500-mm-diameter, schedule 10 pipe, made of S30403 stainless steel. The lines are insulated to prevent condensation.

Source : Magazine, NICKEL, Vol. 16, No 4, June 2001, Pg. No. 8-9
www.nidi.org/nickel/0601/8.html

STAINLESS STEEL WATER STORAGE TANKS: THE RIGHT CHOICE

Stainless Steel
Water Storage Tanks: The Right Choice

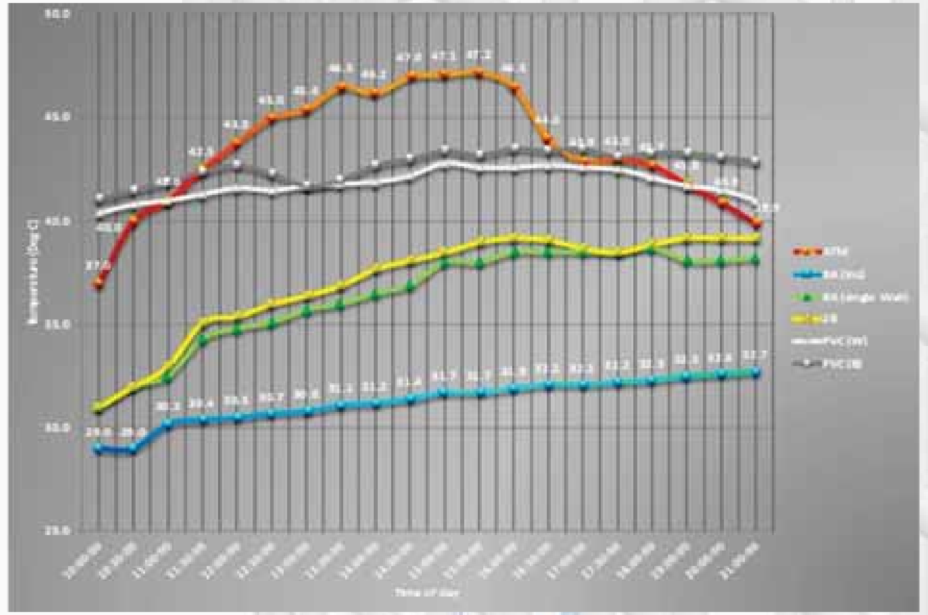
Potable water is a very serious problem not only in India, but the world over. Water quality has been drastically deteriorating over the years due to pollution and environmental degradation. Water is one of the most essential requirements for all of us. The purity of water significantly depends upon the characteristics of material in which it is stored and used.

The property of Stainless Steel in maintaining the purity and hygiene of food and drinks is well known to everyone. We are already using Stainless Steel in a big way, for milk and food processing, cooking, serving and eating purposes in the form of utensils, containers and various household appliances.

Stainless steel does not absorb pollutants, chemical, pesticides or other contaminants into its surface. If any of these substances find their way into a SS Water Tank one can just wash it out of the tank and re-fill. Depending on the contaminant, a plastic or plastic lined tank may have to be professionally cleaned or in a worst case, thrown away. The advantages of Stainless Steel water tanks are Hygienic - Water remains in its natural form and 100% microbiological safe.

Reduces risk of water borne diseases Compact and aesthetic design No algae/fungus formation Value for money for years Easy to clean and practically maintenance free Total drain out provision provided at bottom of tank for easy cleaning.

Available in 100, 250, 400, 500, 1000, 2000, 3000 plus liters in capacity



*Water Heats less in SS water tank*Graph**

There is a misconception that water will heat up more if stored in a SS tank exposed to sunlight compared to conventional plastic water tanks. ISSDA has regularly been disseminating information on why water in a SS tank is cooler compared to that stored in plastics and galvanized tanks. In a study done by a group of technical experts it was found that the water heats less compared to that stored in plastic made tanks. The experiment was done by recording temperature of the water at regular interval stored in tanks made of different materials. On account of its high reflectivity, stainless steel surface rejects almost 50% of sunlight preventing the water to be heated up during the day and it cools faster during evenings and night because of high thermal conductivity. The detailed results can be analyzed from the graph.

Today double walled Stainless steel tanks are available in market which can guarantee minimum variation in temperature of the water over the day.

An independent assessment of market size of popular plastic (High-density polyethylene - HDPE) tanks estimates it at ~15,00,000 tanks per annum are used for the pusrpose of storing water and is adding to the environmental burden rapidly. With the rapid urbanization, decreasing resources and erratic supply of water will force the citizens to depend more on stored water. Today mostly plastic tanks are being used because of low initial cost even with some inherent disadvantages such as fastwear and tear, less environment friendly, poor hygiene and many cases result in life threatening diseases. But over the years of knowledge sharing has empowered people to understand the benefits of using the right kind of material based on Life Cycle Costing of a productalong with taking care of their seriousconcerns to hygiene.

Certain areas of the country with minimal rain and abundant water shortage, the accumulation of rainwater becomes a necessity and these tanks would prove to be the best alternative for storing of rain water even for drinking purposes with certain precautions during collection.

Although the price of stainless steel water tank of quality AISI 304 is initially higher than the plastic water tank but you are assured of a very long and maintenance free service life. Stainless Steel is fully recyclable and has a good scrap value where as plastic tanks has no scrap value. The life of stainless steel water tank is considered to be 5 times more than any plastic tank.

Stainless Steel Raw Water Pipeline, Mettur Dam, Tamil Nadu Water Supply and Drainage Board (TWAD)

Stainless Steel Raw Water Pipeline, Mettur Dam, Tamil Nadu Water Supply and Drainage Board (TWAD)

Mettur dam in Salem district of Tamil Nadu utilizes water from the Cauvery River for regulating water supply to parts of Tamil Nadu. RawWater from the river is pumped up through pipeline to the pumping house for feeding to the water treatment plant and further distribution by the Tamil Nadu Water Supply and Drainage Board (TWAD).

Until 1997 TWAD was using a carbon steel pipeline and had been facing a host of problems. Due to high rate of corrosion, they had to frequently change the carbon steel pipes to prevent leakages and pressure drops etc. The hilly terrain, with high gradient, posed an added handicap and a headache for periodic repairs and replacements. Figure 1 shows the extent of corrosion in a discarded steel pipeline lying below the present stainless steel pipeline.

Recurring problems with the raw water supply line were creating repeated disruptions in water supply to the treatment plant and in further supply of water to the population.

Role of Salem Steel Plant (SSP)

Hearing about this problem, Salem Steel Plant (SSP) team approached TWAD and the benefits of using stainless steel pipeline were explained to them. They were told that on account of high corrosion resistance and durability of stainless steel, an uninterrupted water supply for 50-

Figure 1. Severely corroded carbon steel pipeline at Mettur dam lying below the 14-year old stainless steel pipeline

60 years can be achieved. Also due to high corrosion resistance, there will be no leakage and related loss of water. The smooth internal surface of stainless steel will offer less resistance to flow, thereby reducing pumping losses and will lead to significant savings in electricity cost over the years.

It was also explained to them that due to high strength to weight ratio, stainless steels are lightweight and easy to install. Considering the hilly region near Mettur dam, the proposed 300 mm diameter stainless steel pipe with 3 mm wall thickness could be easily installed without much heavy lifting equipments.

SSP also explained the economic benefits of using stainless steel. Usage of stainless steel will result in zero maintenance and savings in electricity cost that will far outweigh any higher initial material costs. Salem steel guaranteed the TWAD officials for the quality of water and zero maintenance for 50 years.

TWAD engineers agreed to replace the 320 meter of the raw water pumping main line with 3 mm thick stainless steel (Type 304) pipeline. For last 14 years the newly installed stainless steel pipeline demanded no maintenance. In fact, installation is as good as new. Figure 2 show the status of the pipeline in use after 14 years. It is still free from any sign of corrosion. TWAD has also experienced these benefits of zero maintenance and savings in electricity cost since the stainless steel pipeline was installed.

Figure2 : Stainless steel water pipeline after 14 years of installation at Mettur Dam

STAINLESS STEEL WATER TANKER - DELIVERING CLEAN WATER AT YOUR DOORSTEPS

Stainless Steel
Water Tanker

Stainless Steel Water Tankers Delivering Clean Water At Your Doorsteps

Clean potable water is the right of every citizen in a healthy living environment. With city population swelling up every year, there is an ever increasing pressure for the demand of clean water. Non availability of sufficient potable water is one of the serious concerns for any of the cities. Major efforts are being made to make sufficient service pipe lines, develop better and efficient waste water management systems, reduce leakages of water and develop efficient water transportation systems to transport potable water at the required destination in smallest period of time.

Accordingly, stainless steel water tankers were developed to encash following properties of this material.

Hygienically Reliable

World Health Organization, a a specialized agency of the United Nations (UN) concerned with international public health, in their technical note on 'delivering safe water by tanker' highlights the fact that stainless steel is safe for suitable storage and transportation of potable water. The easy cleaning ability of stainless steel makes it the first choice for strict hygienic conditions.

It has been proved that Stainless steel's cleanability is similar to that of glass and far superior to plastics, aluminium and earthenware.

Lighter and Stronger

When it comes to design, stainless steel offers same strength at lower thickness. Stainless steel (AISI 304) high strength permits the use of lighter gauges than other metals - and at prices competitive with most of them. The tankers for both 3000 & 9000 ltrs capacities are built of 4mm thick sheets and are as light as nearly 500 and 1100 kg respectively. Lower weight helps in achieving higher fuel efficiency. Stainless steel resists denting, nicking and scratching under the most vigorous of operating conditions.

Costs less over the service life

There is increasing awareness that life cycle costs, not just initial cost, should be considered when making a decision considering the fact that expected service life of stainless steel water tankers will be more than 5 times than that of steel tankers. Although the initial cost of each tanker is nearly twice than that of steel tankers but this incremental initial cost is recovered in few years considering the downtime, maintenance and replacement of rusted steel tankers over a period of every 3 to 4 years. Because stainless steel does not corrode under normal conditions and never needs paint, costly maintenance is cut down drastically. Stainless steel is eco-friendly as it is fully recyclable and offers high residual value compared to steel tankers.

Many Municipal Corporations e.g. Delhi, Hyderabad, etc have started using stainless steel water tankers and is being proposed in Smart City concepts. With the increased usage of stainless steel water tankers, it will help in reduced leakage of water and will help in making hygienic potable water available for the consumers.

To overcome the serious shortage of potable water supply, especially in peak summer months, Delhi Jal Board, responsible for production and distribution of potable water in the National Capital Territory of Delhi, runs a fleet of water tankers to fulfil the requirements of its residents. Tankers filled with water is a rapid means of transporting water to areas in need in case of shortage or failure in direct water supply.

In the country, the water supply tankers are conventionally made of carbon steel. In Delhi also the water tankers made of carbon steel have been in use for a long time. Delhi Jal Board's (DJB) started privatising the water tanker management system in the national Capital and awarded the contract to three private companies to run 385 water tankers in 3000 ltrs and 9000 ltrs capacity way back in 2013. The decision to convert the existing carbon steel tankers with stainless steel (AISI 304) was taken after a long discussion between stakeholders. Jal board was explained about the benefits of using stainless steel for potable water system. Once the excellent hygienic properties, high corrosion resistance, longer life, life cycle costing, better strength and formability of stainless steel was explained to them, it was an easier decision to make.

For Delhi Jal Borad (DJB) one of the prime reasons to select Stainless steel was to ensure the hygiene, purity of water and assurance that material will not degrade in service. Thanks to stainless steel excellent corrosion resistance it is one of the best materials to preserve the quality of water. There has been complaint to Delhi Jal Board about the sever rusting of mild steel tanks promoting bacterial overgrowth. The mild steel water tanks has to be painted inside with black coal tar paint which over a periodic use dissolves into the water posing serious health issues.

Source : Jindal Stainless Ltd.

STAINLESS STEEL : AN IDEAL SOLUTIONS FOR LEAK PROOF, MAINTENANCE FREE PLUMBING.

Modern Plumbing Systems in
Stainless Steel Gaining Popularity

Plumbing systems have a huge impact on our modern lives, though we rarely ever think about them until something goes wrong. Plumbing systems distribute water throughout the building as pipes fitted in or around walls run from a water source into and throughout your building to valves and knobs that control water flow to your sinks, tubs, washing machine, and toilets.

A good water piping system increases the life and safety of the building. The most commonly used material for water piping is carbon steel but it tends to corrode heavily over a period of time and can cause leakages and subsequent damages to structure.

With increasing awareness Indian Architects, designers and plumbing consultants have started looking for alternatives to galvanized iron, PVC or copper to meet the demanding performance requirements from customer going for state-of-the art buildings.

Stainless Steel plumbing is often seen as expensive and crafty to work with but the new and innovative “Press Fit Technology” has made stainless steel to be cost effective and easy to install alternative to most systems.

Apart from the material benefits on account of very low corrosion rate in water, its hygienic, high flow rates and high strength there are some direct economic benefits of it such as

- Expected lifetime of stainless steel system is more than 50 years way ahead of many competing materials
- It requires no additional coating
- No maintenance and replacement results in cost saving
- Lower thickness of pipe on account of high strength thus lower material cost
- High flow velocity allows to use lower diameter pipes thus reducing cost
- With press fit technology (75% less installation time) savings in labor cost
- Savings in installation time results in saving in project overruns.

There has been several projects where benefits of stainless steel has been realized. Central Public Works Department under the Ministry of Urban Development, Government of India has gone for fully state-of-art stainless steel plumbing in one of their residential projects in New Delhi. It wasvery first time when CPWD used SS plumbing system in their projects. In three multi story towers AISI 304 grade stainless pipe system with press fit technology was used.

**PIC* - Front of whole Building, Pipe fitted to wall, Press fitting tool old,*

Indian Institute of Technology, Delhiis building a five storylecture hall in their campus in which SS plumbing system is being used.AISI 304 grade stainless pipe system with press fit technology has been used.

PIC - Front of building and Images.

In a recent project done at Central University of Jammu, District Samba, Jammu stainless steel has been preferred for plumbing at high altitude cold region area.

Source : ISSDA

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Stainless steel Conduit complying to ASTM A 269, both ends threaded to
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Finishes:
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Stainless Steel Grades:
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