Stainless Steels and International Drinking Water Applications

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The excellent corrosion resistance of stainless steels can provide society and industry with better water quality and reduced environmental impact at lower cost. There is no general corrosion so there is no need for a corrosion allowance, protective coating, control of water chemistry (except normal biocide treatment) or corrosion protection system. Correct grade selection and good practice minimise the risk of any localised corrosion. Therefore there is very little contamination of water in contact with stainless steel and equipment will last a long time.

A European seminar was organised in Brussels in November 2003 by Euro Inox and CeoCor to highlight the opportunities for more use of stainless steels in the treatment, storage and distribution of drinking water. This article is based on a paper given at the seminar, augmented by highlights of other presentations.

Water purity and approvals

A key feature of stainless steels is that they maintain the purity of the water. This has been demonstrated in European rig tests showed that leaching values for chromium and nickel were less than 5% of the maxima permitted by the European Drinking Water Directive (50 and 20 µg/l respectively). This has been supported by 24-hour stagnation tests carried out by the UK Drinking Water Inspectorate (DWI). The relevant DWI Committee concluded that "... the use of products made from the specified stainless steel grades in contact with water for public supply would be unobjectionable on public health grounds" and this formed the basis for the DWI approval process which was described in *Stainless Steel Industry,* February 2002.

Continuing low leaching levels were shown in a three and a half year study of a stainless steel plumbing system in a Scottish hospital.

Many other countries insist that materials are approved before they can be used in contact with drinking water. (Note that in some jurisdictions, "drinking water" or "water intended for human consumption" is taken to include the water from the point of extraction, before any treatment.) For example, in the USA stainless steels are the only materials approved for use in the public water supply without restriction and they have also been approved there for use in both residential and institutional buildings.

A European Acceptance Scheme (EAS) for Construction Products in Contact with Drinking Water is currently being developed which should come into operation in

Member States in 2006. Stainless steels are well placed to satisfy its requirements.

Any metals which leach into the water may pass into the waste water stream. After treatment, they will then be concentrated in the sewage sludge. There are already some parts of Europe where the metal content of the sewage sludge may restrict its use as an agricultural fertiliser. The low leaching levels from the use of stainless steel in the drinking water distribution system could provide an environmental benefit in this situation.

Durability

The corrosion resistance of stainless steels means that not only will they last a long time in drinking water applications without replacement but also they will be relatively maintenance-free, so reducing operating costs. However, the benefits do not stop there because when the installation is no longer needed stainless steels still have residual value and so are likely to be fully recycled. Reducing all these costs to present day values allows a true cost comparison to be made (Life Cycle Cost analysis) and stainless steel is then often the most cost-effective choice. There are signs that some authorities are now requiring such long-term financial justification of projects, for example Italy and the USA.

Since there is no general corrosion, there are no corrosion products to deposit on internal surfaces which would reduce both the bore and smoothness of the pipe. In turn, this means that the initial flow characteristics of the system will not be impaired, so no extra flow or pumping capacity will be needed during the lifetime of the application - unless there are deposits for other reasons. This was one of the factors which led to the choice of stainless steel as a replacement for a raw water line in India, see Figure 1.

Figure 1. The first use of a stainless steel pipe to handle raw water in India. 300 mm diameter: lower weight meant lower transport and installation costs; no corrosion meant that pumping efficiency would be maintained. Compared with

cast iron, these advantages resulted in a lower life cycle cost over the required 50 years.

Tokyo had a big problem with leaks in the service pipes connecting the water main in the street to the building. A replacement programme was started more than ten years ago using stainless steel pipes. Recently a novel corrugated pipe was introduced which can be bent easily and reduces installation cost, see Figure 2. The programme has been so successful that it has avoided the alternative solution of building another reservoir.

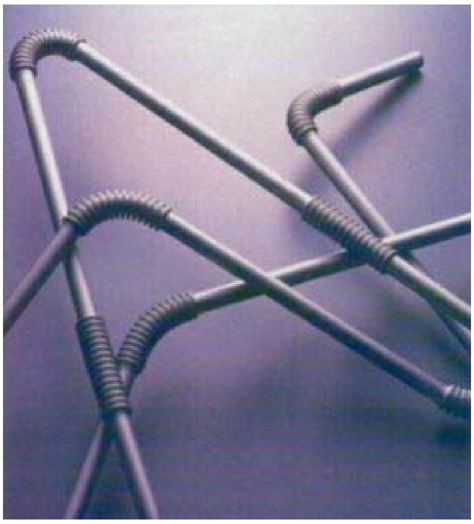

Figure 2. Corrugated, flexible pipes used for rapid, leak-free service pipe installation in Tokyo, Japan.

Lightweight installations

The good ductility, strength, weldability, resistance to high water flow rates and corrosion resistance of stainless steels combine to enable lightweight structures to be used. Thin-walled tubes may be used which can be joined by welding, or by flaring and using loose flanges. In turn, this leads to easier transport to site, greater capability for offsite shop fabrication (better control and cheaper), easier installation without heavy lifting equipment and lightweight supporting structures. The installed cost may then be less than the cost of using a more traditional material, in spite of the higher cost per kilogram of stainless steel. The higher strength of the duplex grades may allow further savings, for example large diameter buried pipelines or pipes spanning wide gaps.

The example in Figure 3 is from a sports stadium in the USA where stainless steel was selected for the principal 350 mm diameter drinking water line, primarily because its lightweight meant that it could be installed by two people using simple lifting equipment.

Figure 3. 300 mm drinking water main pipe, light enough to be installed by two people in a new sports, stadium in Detroit, USA.

Examples of recent applications

Water storage

Stainless steel is now being used to line drinking water reservoirs - both new and refurbished, see Figure 4.

Figure 4. Reservoir in Italy lined with stainless steel. Courtesy of Centro Inox.

Not only is it easy to apply but it provides a very durable and hygienic lining which is easy to clean, resistant to mechanical and dynamic damage, and protects the underlying concrete structure. Typically, 1.5 mm sheets are bolted into place with overlaps, then TIG welded without filler and heat tint removed by brushing before liquid penetrant inspection. In one example, the additional benefits of offsite fabrication and low installation weight resulted in the life cycle cost for a new reservoir being only half that of alternative solutions.

Distribution

There are many old distribution systems in traditional materials which are now suffering through major leakage. Consumers pay for these directly and indirectly. The durability of stainless steels means that their use in distribution networks can reduce the leakage virtually to zero. Trenchless technology has been used in Italy refurbish water mains whilst avoiding serious disruption to heavy city centre traffic. Extensive development work was undertaken to produce a system which allowed lengths of pipe to be joined by orbital welding in small excavations and then pushed up to 1000 m along the existing main - even accommodating deviations of 15°. See Figure 5.

Figure 5. Refurbishment of water main in Padua, Italy using trenchless technology to avoid disruption. Lengths of pipe are orbital welded in the excavation and then pushed hydraulically along the old main.

Studies in the USA are now showing that stainless steel may also be an economic alternative to traditional water main materials.

Plumbing

A variety of stainless steel plumbing system fittings are now available. Germany has a lot of experience and stainless steel is reported to have about 15% of the market. It is notable that its use has now spread to China, where prestigious new office buildings are being plumbed in stainless steel, see Figure 6. The BSSA produced a special report in February 2003 to encourage further penetration into the UK market.

Figure 6. Plumbing system in new telecommunications building in Xi'an, China.

Remarkable growth has taken place in the number of Italian stainless steel tap manufacturers - from none in 1997 to 17 in 2002. Whilst fashion undoubtedly plays a part, the major driving forces are improved water quality and durability of the tap under heavy domestic use. Both castings and wrought material are used, see Figure 7.

Figure 7. Italian stainless steel tap. Courtesy of Centro Inox.

Good practice in the selection and use of stainless steels

In common with all other materials, stainless steels will only perform at their best if grade selection, design, fabrication, commissioning, operating and maintenance are all carried out correctly. This is recognised in guidance documents, standards (e.g. in Germany), and the Operating Guidelines and

Code of Practice which are a necessary part of the UK Drinking Water Inspectorate's approval of stainless steel products.

Grade selection

Only a small number of grades of stainless steel are in common use with drinking water. Practical experience and tests have shown that the chloride content of the water is the most important parameter in grade selection because of its influence on localised corrosion - crevice corrosion in particular. This has led to the guidelines in Table 1 for ambient temperatures, although other grades with equivalent corrosion resistance may also be suitable.

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

Table 1. Chloride level guidelines for waters at ambient temperatures.

When it is necessary to handle hot water or when more conservative guidelines are necessary, then upper chloride limits of 50 ppm for 1.4307 (304L) and 250 ppm for 1.4404 (316L) may be appropriate.

Design and fabrication

After grade selection, the most important aspect of design is to minimise the opportunities for crevice corrosion at joints by use of welded connections or good detailing.

Galvanic corrosion of other materials in contact with stainless steel does not seem to be a practical problem if copper-based fittings are used with stainless steel pipes in a plumbing system. However, if cast iron, carbon steel or galvanised steel is used in conjunction with stainless steel, then electrical insulation between the different metals may be necessary.

Equipment design also extends to ensuring that treatment chemicals are injected and mixed properly, since in concentrated form they can be aggressive to stainless steels. For example, chlorine injection should be into the middle of the water stream to ensure good mixing, rather than adjacent to the wall of a pipe where mixing may be poor leading to high local concentrations.

There is plenty of guidance available on welding of stainless steels, and housekeeping during material storage and fabrication. Attention must be given to making full-penetration welds and eliminating (or at least minimising) heat tint if the best corrosion performance is to be obtained, see Figure 8.

Figure 8. High standard of fabrication of pipework in a drinking water treatment works, Germany.

Iron contamination may only cause cosmetic rust staining on plant but experience around the world is that clients see it as something unexpected and wrong with the stainless steel. It is easily prevented or removed - and should be.

Obtaining more information

Drinking water has been recognised as a market where there are clear opportunities to increase the use of stainless steels in drinking water applications to the benefit of society and the environment. Further information and guidance on good practice may be obtained from the BSSA's website www.bssa.org and from www.stainlesswater.org, the "Water Portal" on NiDI's website.

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