

Characterization of ATI 2102[®] Lean Duplex Stainless Steel Pipe used for Water Distribution

Presenter:



David Bergstrom

Manager, Product Development, ATI Allegheny Ludlum

Academic Education and Degrees:

1995 Doctoral Thesis on High-Strength Austenitic Stainless Steels,
Northwestern University, Evanston, IL, USA

1989 Bachelor's Degree in Metallurgical Engineering,
University of Illinois, Champaign-Urbana, IL, USA

Characterization of ATI 2102[®] Lean Duplex Stainless Steel Pipe used for Water Distribution

David S. Bergstrom

ATI Allegheny Ludlum, an Allegheny Technologies company

Keywords: Lean Duplex Stainless Steel, ATI 2102[®], S82011, Pipe

ABSTRACT

ATI 2102[®] alloy (UNS S82011) is a recently developed, lean duplex stainless steel (LDSS). With a composition containing approximately 21.5% Cr and 1.5% Ni, ATI 2102 LDSS has strength and corrosion resistance superior to that of Type 304L stainless steel. Its higher strength may allow thinner sections of ATI 2102 LDSS to replace components made with thicker sections of stainless alloys like Type 304L. The fact that there is no need for a corrosion allowance when using stainless steels may enable additional gauge reduction to be made when replacing articles made from carbon steel or ductile cast iron. This substitution may result in considerable cost savings. One application where such substitution should be considered is in pipes used for water and wastewater distribution. The strength, toughness, corrosion resistance, and weldability of ATI 2102 LDSS make it a good choice for use in water piping applications. In this paper, the properties of ATI 2102 LDSS will be reviewed, and details of the fabrication and application of ATI 2102 LDSS pipes made for a water reclamation project will be detailed.

[®] Registered trademarks of ATI Properties, Inc.

1. INTRODUCTION

Lean duplex stainless steels (LDSS) are a relatively new sub-group of duplex alloys that have been developed to be cost-effective alternatives to the well-established 2205 (UNS S32205) duplex stainless steel as well as to commonly used stainless steels such as Types 304L (UNS S30403) and 316L (UNS S31603).^{1,2} As illustrated in Table 1, duplex alloys such as ATI 2102[®] LDSS (UNS S82011) and ATI 2003[®] LDSS (UNS S32003) are considered lean because they contain a lower percentage of the expensive alloying elements Ni and Mo than does 2205, and much less Ni than do Types 304L or 316L.

Table 1. Nominal compositions of ATI 2102[®] and ATI 2003[®] LDSS alloys compared to 2205 duplex and Types 304L and 316L.

Alloy	Cr	Ni	Mn	Mo	N	PRE _N
304L	18.1	8.1	1.0	0.3	0.05	20
316L	16.1	10.1	1.0	2.1	0.05	24
ATI 2102 [®]	21.5	1.5	2.8	0.3	0.2	26
ATI 2003 [®]	21.5	3.8	1.5	1.8	0.17	30
2205	22.5	5.1	1.5	3.3	0.17	36

When comparing the corrosion resistance of different stainless steels, it is convenient to use an equation such as the one shown below.

$$PRE_N = \%Cr + 3.3 \%Mo + 16 \%N \quad (1)$$

The PRE_N (Pitting Resistance Equivalence Number) was developed to rank an alloy's resistance to the initiation of pitting corrosion in a chloride-containing environment when compared to similar alloys. While PRE_N does not predict an alloy's corrosion rate or its performance in other environments, it does a fairly good job of ranking an alloy's expected performance in critical pitting tests conducted in chloride solutions, such as those in ASTM Standards G48³ and G150⁴. As the data shown in Figure 1 demonstrate, a linear relationship exists between the PRE_N and the Critical Pitting Temperature (CPT) of the alloys listed in Table 1 as measured by the method of ASTM G150.

[®] Registered trademarks of ATI Properties, Inc.

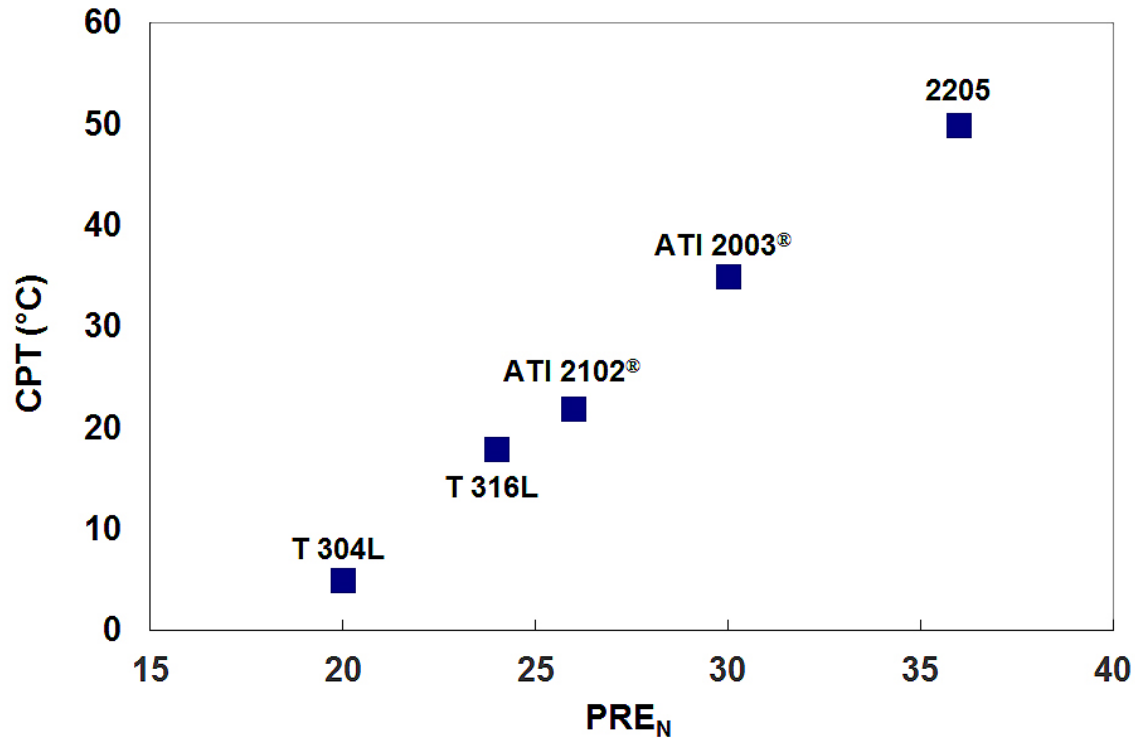


Figure 1: Critical Pitting Temperatures plotted against Pitting Resistance Equivalence Numbers (PRE_N) for the alloys in Table 1.

The data in Figure 1 shows that the LDSS alloys have CPT's between those of the austenitic alloy T 316L and 2205 duplex. In addition to their high resistance to the initiation of pitting, duplex grades are generally more resistant to stress corrosion cracking (SCC) than are comparable austenitic alloys. As seen in Table 2, the duplex alloys did not crack in a 1000-hr SCC test in a boiling 26% NaCl solution, whereas Types 304L and 316L failed the test.

Table 2. Results of SCC Testing in a boiling 26% NaCl solution

Alloy	Result
304L	Cracked in 850 hours
316L	Cracked between 530 and 940 hours
ATI 2102®	Did not crack in 1000 hours
ATI 2003®	Did not crack in 1000 hours
2205	Did not crack in 1000 hours

In addition to their good corrosion resistance, LDSS alloys have much higher strength compared to most austenitic grades. Table 3 shows that the typical yield strengths of the duplex grades are roughly twice those of Types 304L and 316L, and the tensile strengths are also significantly higher.

Table 3. Typical tensile properties

Alloy	Yield Strength Ksi (MPa)	Tensile Strength Ksi (MPa)	Percent Elongation
304L	40 (275)	90 (620)	55
316L	40 (275)	90 (620)	55
ATI 2102 [®]	80 (550)	110 (760)	35
ATI 2003 [®]	75 (515)	105 (725)	40
2205	85 (585)	125 (860)	30

This strength advantage, along with their good corrosion resistance, makes LDSS alloys attractive alternatives to austenitic stainless steels for many applications. Some examples include storage and transportation tanks for a variety of substances, structural applications, flowlines and umbilical tubes for the oil & gas industry, and equipment in pulp & paper mills and in water treatment facilities.

This paper will focus on one specific application of lean duplex material: the selection, fabrication, and installation of ATI 2102 LDSS pipes used in a water reclamation project.

2. ATI 2102[®] LDSS Pipes for Water Reclamation

The water industry often uses carbon steel or ductile cast iron piping for water distribution. Besides the obvious advantage in corrosion resistance, stainless steels have several other advantages over these materials⁵. For example, stainless steels have greater impact resistance, especially at cold temperatures. Another is that their higher strength can allow for thinner-walled pipes to be used, resulting in weight savings that can result in a lower total cost, once transportation, installation and maintenance costs are included. When all of the advantages of stainless steel are considered, the total life-cycle costs of stainless steel pipes can be much lower than those of ductile cast iron piping, especially if the costs of a water main break are included. Figure 2 shows the catastrophic results of a fractured 36-inch (914 mm) cast iron water main in downtown Pittsburgh in 2005. Millions of dollars in damage were caused by this one failure⁶. Stainless steel pipes are much more resistant to brittle fractures, such as the one that caused this disaster, than are cast iron pipes.

For water treatment, the use of stainless steels is already common. Types 304L and 316L are often used in piping and equipment in water treatment facilities.

Many of these applications should be considered as potential candidates for the use of LDSS alloys.



Figure 2: The top image shows the flooding in downtown Pittsburgh that resulted from the fractured cast iron pipe shown in the lower image⁷.

2.1 Talking Water Gardens

One example of a LDSS being used for water treatment is in the Talking Water Gardens, an “engineered wetlands” being built for the final treatment and cooling of approximately 12.5 million gallons (47.3 million liters) of wastewater per day

from the ATI Wah Chang plant and two adjacent cities in Oregon, USA.⁸ The name “Talking Water Gardens,” is derived from the sound made by the many waterfalls that are used to cool and aerate treated wastewater from ATI Wah Chang and the municipal water reclamation facility before it is returned to the Willamette River. Cooling the water is necessary because warm water can be harmful to aquatic life, such as the river’s salmon population.⁹



Figure 3: Drawing of the Talking Water Gardens wetlands site.⁶

When the facility was being designed, the preliminary specifications called for pipes used in the facility’s pumping station to be made from Type 304L stainless steel. After discussions with ATI Allegheny Ludlum, it was agreed that this application would be a good project in which to demonstrate the capabilities of ATI 2102 LDSS. As will be described, a portion of the T304L piping in the

pumping station was replaced by ATI 2102 LDSS in such a way as to allow the alloy's performance to be evaluated over many years.

2.2 Fabrication of ATI 2102[®] LDSS Components

ATI 2102 LDSS was used to produce both pipes and flanges for the Talking Water Gardens pumping station. The pipes were made from 0.25 inch (6.35 mm) thick coiled plate material and the flanges were machined from a 1.5 inch (38.1 mm) thick discrete plate. The nominal composition of the ATI 2102 material used for this project is shown in Table 4.

Table 4. Nominal composition of the ATI 2102[®] material used in the Talking Water Gardens project

	C	Mn	P	S	Si	Cr	Ni	Mo	N
ATI 2102[®]	0.020	2.8	0.025	0.0002	0.3	21.5	1.5	0.3	0.2

The coiled material was used to make 800 feet (183 m) of 14 inch (356 mm) Schedule 10 pipes in 40-foot (12.2 m) lengths. The pipes were welded using standard duplex welding procedures¹⁰ and type 2209 duplex weld wire. Figure 4 shows a picture of the welded pipes as they arrived at the fabricator's facility.



Figure 4: 40-foot lengths of ATI 2102[®] LDSS pipe.

The fabricator welded ATI 2102 flanges to the ends of the pipes using 2209 filler metal. Type 304L aerators were also welded to a section of ATI 2102 pipe as shown in Figure 5. Welding of LDSS materials to austenitic alloys such as Types 304L and 316L is commonly done with good results. In this case, 2209 filler metal was used to weld the T304L aerators to the ATI 2102 pipe. However, 309LMo wire should also give satisfactory results when welding these two stainless steels together.

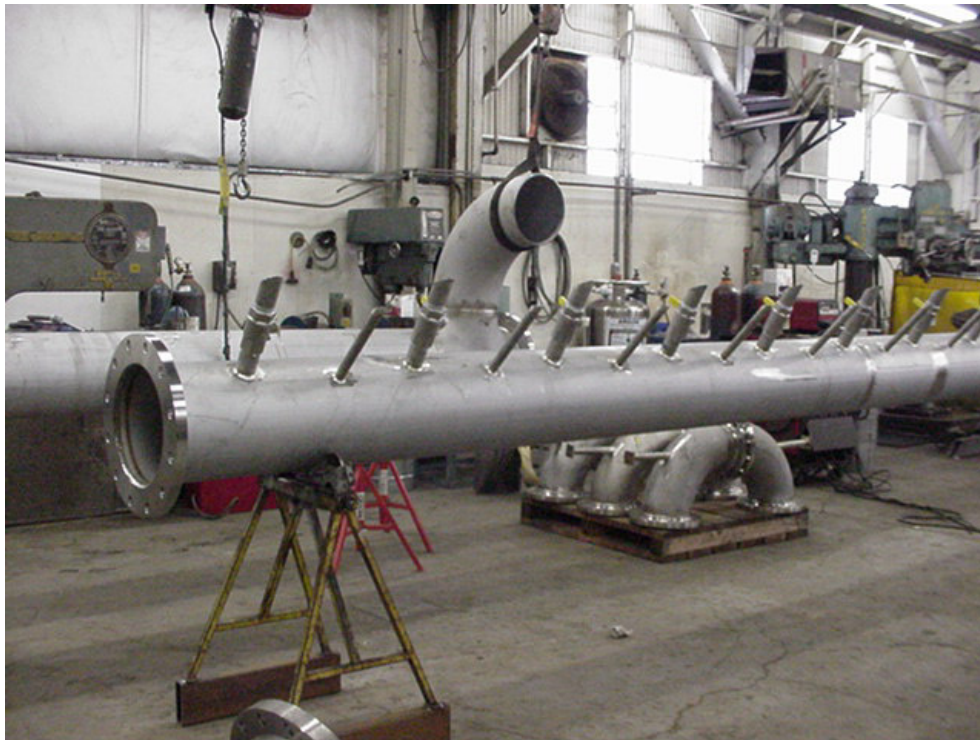


Figure 5: Type 304L aerators welded to an ATI 2102[®] pipe.

Figures 6, 7 and 8 show how the various ATI 2102 LDSS components were installed at the Talking Water Gardens pumping station.



Figure 6: ATI 2102® pipes as installed at the pumping station.

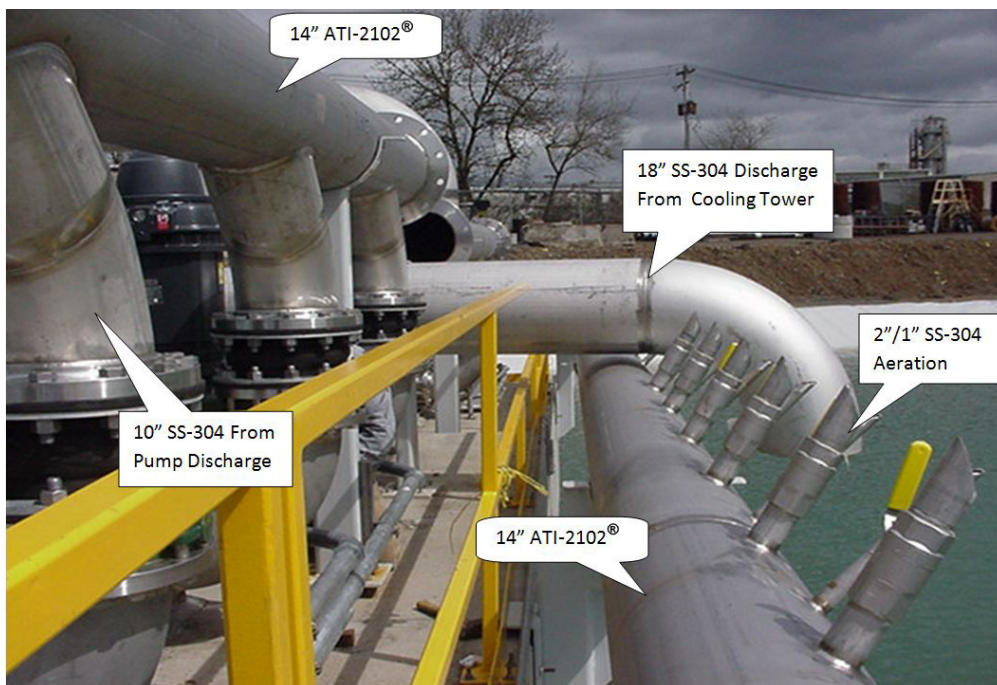


Figure 7: Detail showing locations of ATI 2102® LDSS and Type 304L.

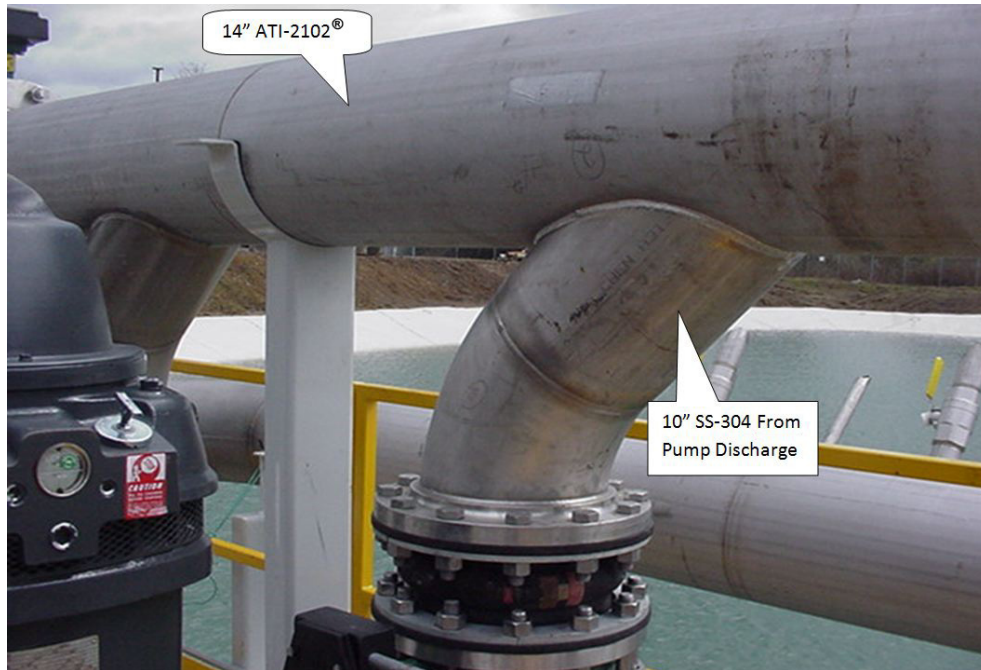


Figure 8: Detail showing Type 304L discharge pipe connected to ATI 2102® LDSS pipe.

3. Characterization

3.1 Service Conditions

The water flowing into the Talking Water Gardens pumping station was characterized as containing less than 2,000-ppm chlorides with traces of ammonia. The average temperature of the water is expected to peak at about 73°F (23°C) during the summer months.⁷ If the average chloride levels are close to 2,000-ppm, then this will be a very challenging environment for Type 304L and will be a good test to determine the service limits for ATI 2102 Alloy. According to literature, Type 304L will be susceptible to crevice corrosion and pitting in water service when the chloride content exceeds 200 ppm, and such corrosion would be likely during extended service in water containing more than 1,000-ppm chloride.¹¹ Type 316L is more resistant than T304L, and rarely experiences pitting or crevice corrosion below about 1,000-ppm. However, it may be susceptible to such attack between 1,000 and 2,000 ppm. As shown in Figure 1, fully annealed ATI 2102 LDSS has a slightly higher critical pitting temperature than does T316L. Therefore, in the annealed condition, it ought to resist the initiation of pitting and crevice corrosion at slightly higher chloride levels than does Type 316L. In the as-welded condition, the pitting resistance of ATI 2102 LDSS may drop below that of T316L in the heat-affected zone. However, ATI 2102 pipe welded with an over-alloyed filler metal, such as 2209, should provide

a substantial improvement over as-welded T 304L pipes in the Talking Water Gardens application, especially during the times when the chloride content of the water approaches 2,000-ppm.

3.2 Evaluation of Performance

In order to evaluate the performance of the ATI 2102 LDSS in comparison with the Type 304L stainless steel used for this application, three test spools were installed at the pumping station. Each of these spools consists of one-foot lengths of Type 304L and ATI 2102 pipes welded together and connected in series by ATI 2102 flanges welded to each end, as shown in the schematic diagram in Figure 9.

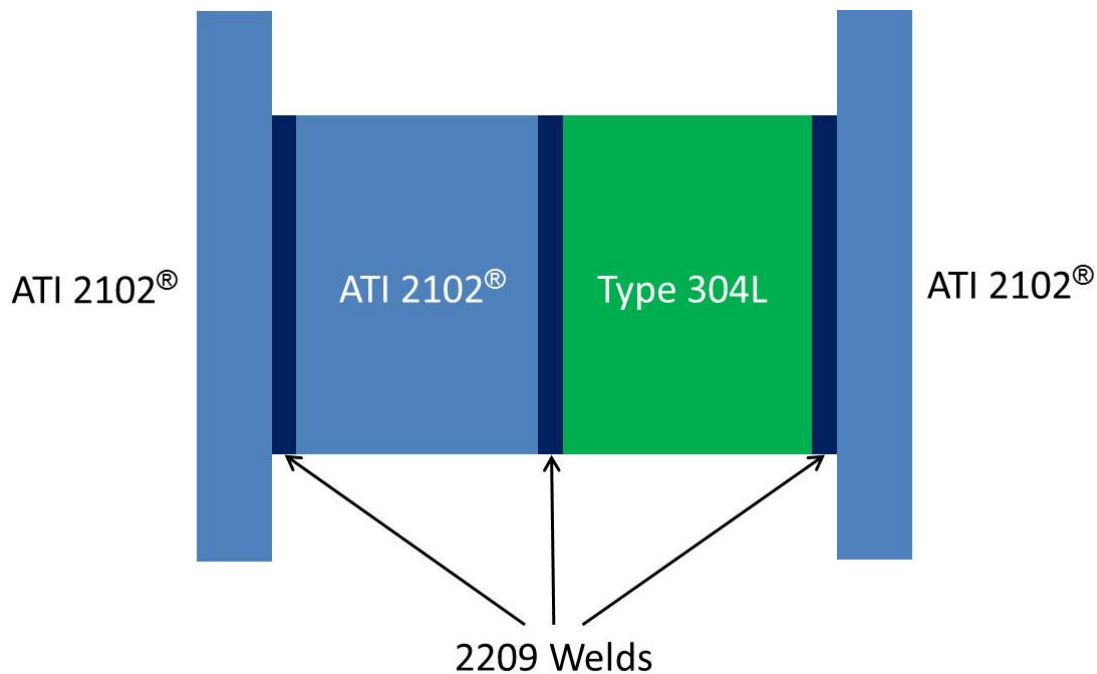


Figure 9: Schematic diagram showing configuration of test spool.

The plan is for each of these spools to be removed at selected intervals for examination and characterization of their performance in service. The removed sections will be inspected for signs of pitting or crevice corrosion, or any other damage that may be present. Figure 10 shows the test spools as installed at the Talking Water Gardens pumping station.



Figure 10: Picture of test spools as installed at the pumping station.

4. Conclusions

ATI 2102 LDSS pipes have been used in place of Type 304L pipes for a portion of a pumping station at the Talking Water Gardens water reclamation project in Albany, Oregon, USA. The potential for elevated chloride content in the treated wastewater could result in a challenging environment for these alloys, and the performance of the pipes will be monitored closely during service, as will variations in the quality of the water flowing through them. At selected intervals during service, test spools consisting of Type 304L pipe welded to ATI 2102 pipe will be removed from service and examined for signs of corrosion or any other deterioration that may have occurred. The results of those characterizations will serve as the basis for a future paper.

References

¹ D. S. Bergstrom, J. J. Dunn, and D. R. Hasek, *Benchmarking of Duplex Stainless Steels vs. Conventional Stainless Steel Grades*, Duplex 2007 International Conference and Exposition, Grado, Italy, June 2007.

² D. S. Bergstrom, C. A. Botti, and J. J. Dunn, *Properties and Applications of ATI 2102™ Alloy, a New Lean Duplex Stainless Steel*, Stainless Steel World 2009 Conference, Maastricht, The Netherlands, November 2009.

³ ASTM Standard G48-03(2009), *Standard Test Methods for Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution*, Annual Book of ASTM Standards, Vol. 03.02, ASTM International, West Conshohocken, PA, 2009.

⁴ ASTM Standard G150-99 (2010), *Standard Test Method for Electrochemical Critical Pitting Temperature Testing of Stainless Steels*, Annual Book of ASTM Standards, Vol. 03.02, ASTM International, West Conshohocken, PA, 2010.

⁵ Brochure, *Stainless Steel Pipe – The Clear Choice for Pure and Reliable Water Systems*, SPLASH, Inc, Huntington, WV, 2008.

⁶ WTAE television report on August 30, 2007, transcript obtained from www.WTAE.com.

⁷ *Pittsburgh Tribune-Review*, August 18, 2005.

⁸ *Constructed Wetlands Will Cool Blend of Municipal, Industrial Water*, Civil Engineering, Vol. 80, No. 6, June 2010, pp. 31-33.

⁹ *Albany-Millersburg Talking Water Gardens*, Project Summary from www.cityofalbany.net, Albany, OR, August 2010.

¹⁰ D. S. Bergstrom, K. J. Schott, and J. J. Dunn, *Welding Optimization of ATI 2102™ (UNS S82011) Lean Duplex Stainless Steel*, Duplex World 2010 Conference, Beaune, France, October 2010.

¹¹ C. Powell and D. Jordan, *Fabricating Stainless Steels for the Water Industry*, Nickel Institute Reference Book Series No. 11 026, 2005, p 14.