NU-TECH
Precision Metals

THE DEVELOPMENT AND MANUFACTURE OF SIZE FOR SIZE FEEDER PIPE FOR FEEDER REPLACEMENT

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1. HISTORY

In 2003 Ontario Power Generation began to address the problem of thinning feeder pipes. The utility was faced with replacing existing 2″ and 2 ½″ pipe at its three operating stations. The original supplier of the SA106 Grade B feeder pipe had decided to exit the specialty nuclear class pipe many years prior. Further, the required production quantities were insufficient and the specifications so demanding that no traditional carbon steel pipe manufacturer could be located. The problem was further exacerbated by the requirement that the pipe be replaced with size for size product. As a result, normal pipe tolerances and sizes could not be employed but rather had to be molded to existing feeder pipe. In addition, pipe sizes varied from reactor site to reactor site as did the applicable code year.

This paper will document the processing and development of size for size replacement feeder pipe for Candu reactors.

2. RAW MATERIAL

Feeder pipe has traditionally been manufactured from SA106, Grade B steel. However restrictions on Cobalt and Antimony as well as the cleanliness limits, particularly on globular oxides, greatly limited the number of potential steel suppliers.
Nu-Tech's starting billet was required to be 7" round and we initially wanted only several thousand pounds of material for trial purposes. Normal mill minimums from large pipe-mills are on the order of several hundred thousand pounds.

The combination of billet size, required steel quality, and small quantities led us to source raw material from the open die forging industry. Raw material for this industry is often supplied from relatively small 80 ton electric arc furnaces followed by aluminum de-oxidation and chemical adjustments at a ladle station. The molten steel is protected from oxidation using a synthetic slag and stirred with argon. As product is melted from selected scrap ferro, cobalt levels are generally quite low as compared to BOF, product which used a pig iron input. Another advantage of accessing material through the open die forging network was that ingots and blooms are typically stocked in two grades that meet SA106 Grade B. They are A/SA 105 and A/SA LF2 which are used principally for forged flanges, weldlets and other fittings which ultimately are welded to SA106 pipe to produce a piping system.

Larger open die forge shops might have a number of heats of such material available and as such it was relatively straight forward to find a low cobalt heat that met the restricted chemistry of O.P.G's 3 code effective dates. As carbon steels are used as "wash heats" by specialty steel facilities there was also a wide range of residual Cr levels to select from. There are currently two requirements, Cr at the 0.10 level to meet traditional Cr levels, and Cr closer to 0.3 which is more in line with modern design. Cr aids in raising material strength, hardness and corrosion resistance in order to minimize wall thinning.

Current demand levels for replacement feeder pipe are high enough that Nu-Tech is able to order custom heats of SA106 Gr. B and tailor chemistry to exactly what the customer demands.

3. PIPE SIZING CONSIDERATIONS

O.P.G's initial feeder pipe specification was written considering the final sizing requirements for the pipe by the station. Figure #1 provides the sizes initially proposed for 2" pipe at the three stations. The reader will note the following:

1) Each station requires a discrete pipe size but it is classified as a 2" sch. 80 pipe
2) Pipes were designed with a +/-0.01 tolerance on the ID.
3) For each lot of produced pipes the OD had to fit within +/-0.031". Later it was discovered that due to bending die considerations, all pipes produced (months or years apart) had to fall within +/-.03" pipe.
4) Minimum wall was presented to the manufacturer as a manufactured minimum when O.P.G's real intent was this was a final product minimum. For the case of Pickering B or Darlington where pipe is bent; there was an error in not considering the potential 12% wall thinning experienced in bending.

Figure #2 provides a summary of the development of the replacement feeder pipe specification. The salient point in the evolution of the specification was the realization that the feeder pipe system had to meet ASME 16.9 requirements for minimum pipe walls. On average a feeder pipe thins by about 10% when bent. This then evolved to require the manufactured pipe be made to a minimum pipe wall 12 ½% greater than the desired minimum (.191 for a 2" sch. 80) for the system. The 12 ½% is consistent with normal pipe and fitting wall tolerancing.

The challenge to the manufacturer then was to produce the pipe to an exacting ID tolerance which met existing pipe (some 8 x tighter than permitted by ASME 16.9) and hold tighter OD and wall tolerances.

4. QUALITY COMPLIANCE

Much of the quality compliance with the specification is routine and of no issue providing proper considerations it gives to steel melting, forging, extrusion, cold drawing and heat treatment. Such routine specification requirements include: product analysis, tensile, bending, flattening, macrostructure, cleanliness and hydrostatic testing.

Nu-Tech now was to develop a product that could meet the dimensional tolerances. We also faced challenges in developing a product that met OPG's rigorous demands for ultrasonic inspection.

Standard SA106 pipe (or any other ASME Code seamless pipe for that matter) is not ultrasonic inspected. Both Nu-Tech and O.P.G. from it's Pick A re-tubing project, were very familiar with Nu-Tech's ability to U.T. test pipe and what was possible. Specific attention was paid to the clarity of back wall reflection (which was driven down to about 5% of full screen height) from the 4 steer wave probes, Figure #3, which drove the product to have a smooth, oxide free surface. This, as explained later, led the requirement for a vacuum heat treated feeder pipe.

OD micrometer measurements along the length of 20 to 40 ft. pipe are straightforward. ID measurements taken at discrete points along the length are possible but more difficult. As O.P.G. was addressing a wall thinning problem there was understandably a great deal of thought given to wall thickness compliance. The reader is reminded that while an ASME Code pipe specifies a minimum wall, there is no defined way in the code to measure this and, indeed, pipe manufacturers rarely do measure wall. Figure #4 describes reasons for wall thickness variation in seamless pipe.

In the end it was determined that 100% of the tube would be inspected to ensure wall compliance. This was accomplished with a normal beam transducer, Figure #3, included in the UT test. It should be pointed out that traditional pipe and even traditional feeder pipe would not receive such scrutiny. A small short draw mark or pit, which is an unacceptable UT defect could create an extremely discreet undersized wall. Such a situation in historically supplied feeder pipe would be acceptable, but would not be acceptable to the replacement feeder pipe specification.

5. PROCESS DEVELOPMENT

There was significant specification modification once O.P.G. purchasing, design and materials engineering began working with Nu-Tech (Figure #5). Aside from size modifications in the spec. previously discussed there were several changes with the manufacturing process. These changes were included:

1) Modifications to Nu-Tech's extrusion process to accommodate carbon steel.

2) Modifications to cold draw sequences and heat treatment cycles and methods to produce clean ultrasonic signals to match the method the original pipe was produced in the 70's and 80's.

3) Modifications to extrusion sizes to develop a master extrusion size that once cold drawn could make any station's pipe.

4) Development of UT inspection techniques and tooling to accommodate simultaneous 5 probe UT on a small pitch.

6. CONCLUSION

As a result of a strong collaborative effort between O.P.G. and Nu-Tech Precision Metals, we have been able to successfully develop the manufacture of replacement feeder pipe for O.P.G. Nuclear Stations.

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FIGURES

FIGURE #1

2” Feeder Pipe Sizes

Reactor	Inside Diameter	Outside Diameter	Nominal Wall Thickness	Minimum Wall Thickness
Pickering “A”	1.925	2.393	.234	.205
Pickering “B”	1.925	2.361	.218	.191
Darlington	1.939	2.375	.218	.191

FIGURE #2

Pipe Sizing Tolerances vs. Standard – Threading the Needle

	OD	ID	Spread	Wall	Spread
Standard 2” Sch. 80	2.375 +/-.031 Spread 2.406 .062 2.344	2.024 1.855	.169	0.245 +/- 12.5% 0.218 0.191	.027
Pickering “B” 2”, Rev. 01	2.361 (Ref) 2.307	1.925+/- .010 1.935 1.915	.020	.218 Nom. .191 Min.	
Pickering “B” 2”, Rev. 03	2.421 * 2.351	1.935 1.915	.020	.243 Max. .218 Min.	.025

*Spread of OD to ID .070

Comparison of Allowable Tolerance Spread of 2” Sch. 80 to Pickering “B”, 2” Feeder Pipe

	OD	ID	Wall
2” Sch. 80	.070	.169	.027
Pickering “B”	.062	.020	.025

FIGURE #5

Modifications to O.P.G. Replacement Feeder Pipe Specification

Purchase	No Change
7″ Diameter Round	No Change
Cut to Length – 24″	No Change
Machine ID ~ 2.4″	No Change
Machine OD Concentric to ID ~ 6.93″	No Change
Encase OD and ID in Copper Heat 1850˚F	OD in Copper, ID Bare Extrude Using Glass ID Lube @ 1740˚F Blast + Pickle to Remove Glass
Extrude Normalize 1600˚F Pickle to Remove Copper	Grind OD to Remove Copper
Draw to Size Rev 1	1st. Draw 2nd. Draw to Size Rev 4
Stress Relieve Tensile, Bend, Flatten Test Hydrostatic Test	Vacuum Normalize Hydrostatic Test
U.T. Test for Defects Dimensional Inspection of Ends	U/T Test for Defects and 100% Wall Thickness Measurements. More Frequent OD Measurements.
Package	Package