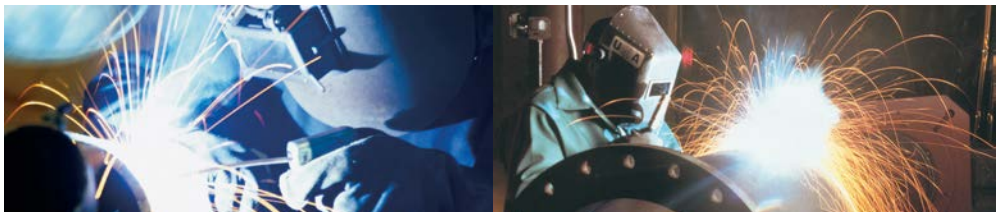
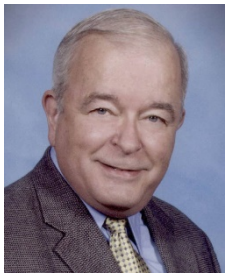
NCPWB Technical Bulletin May 2016





Contributed by
Walter J. Sperko, P.E.,
NCPWB Consultant

Changes in steelmaking practices by certain mills over the last 5 years have resulted in seamless carbon steel pipe, fittings and flanges failing during hydrostatic testing. This article recommends that, except when the piping system hydrostatic test pressure is less than 20% of the code maximum allowable pressure, contractors should include a requirement in their purchase orders that seamless carbon steel pipe, fittings and flanges have a manganese-to-carbon ratio of 5:1 or greater and a grain size of 7 or finer to avoid such failures.

Risk of Brittle Fracture of Carbon Steel Piping During Hydrostatic Testing

At B31.3 meetings in Seattle April 2016, a history of recent failures during hydrostatic testing in A105 flanges, A234 carbon steel fittings and A106 and A53 seamless pipe in piping that was 1/2 inch thick and thinner was presented to the committee members. The committee was advised that failures were in new construction, that the nature of the failures was brittle fracture and that there have been dozens of them over the last 5 years. Typical hydrostatic testing temperatures were 50°F, but some piping in Southeast Asia failed at higher temperatures. Failed material was found to be brittle; Charpy V-notch impact toughness at 70°F revealed toughness in the low single-digits (3 ft-lbs), whereas toughness higher than 40 ft-lbs was normal at that temperature.

Unlike the "Chinese Flanges" issue in the 1990s, analysis of these failures showed that there was no obvious correlation with location of manufacture or country of origin.

The cause of low impact toughness resulted from a gradual change in the chemical composition of steel from what was normal prior to five years ago. In an effort to reduce the cost of making steel, manganese, which is added to improve soundness, toughness and increase strength, was reduced to the lower limit of the specifications (but still within specification limits) and replaced with very small quantities of elements such as vanadium, niobium, titanium and boron to increase strength and formability. In the 1950s, the steel industry determined that, in order for carbon steel to have adequate toughness (20 ft-lbs minimum) down to minus 20°F, the manganese-to-carbon (Mn:C) ratio needs to be 5 or higher. Some of the failed steels had a Mn:C ratios as low as 1.8, resulting in poor toughness leading to failures during hydrostatic testing. There are also some issues related to niobium, vanadium, titanium and boron additions since they can further degrade toughness. Boron, in particular, causes directional recrystallization on the 100 crystal plane at 30 to 45° to the pipe axis resulting in very low toughness at 45° to the pipe or fitting axis; this is precisely the direction that maximum shear loading occurs for pipe under pressure, and because this crystal orientation alignment, axial or circumferential impact specimens

will not identify the material as having low toughness. Interestingly, these changes in the chemical composition of the steel have no effect on weldability; one should, however, be careful not to drop these low-toughness material on a hard surface.

In order to minimize the risk of brittle failure during hydrostatic testing, B31.3 is considering modifying the impact testing exception curves in Table 323.2.2A so that these materials have to have a Mn:C ratio of 5 or higher and a grain size of 7 or finer for these materials to use Curve B of the exemption curves. For material not meeting these requirements, Curve A would be applicable and the lowest service temperature would be raised from -10C to +10°C. The earliest that this could occur is the 2018 edition of B31.3. ASME Section VIII will also be taking a similar approach.

While brittleness is a new issue for piping, a similar issue rose with plate materials due to tramp element and microalloying additions fifteen years ago. This issue was addressed in ASTM by modifying A-20 (*General Specification for Plate*) to limit tramp and microalloying element use; long term, A105, A106 A234 and other carbon steel specifications need to be modified to control the Mn:C ratio, grain size and microalloy additions in a similar manner, but that will take time. As a result of the modification of A-20 ensuring that there was good toughness in plates, fittings that are made from plate by forming two halves of a fitting and welding them together do not exhibit this brittleness. The same is true for A53 resistance welded (ERW) pipe.

Recommendations to Avoid Brittle Failure

First, determine the hydrostatic test pressure, and if it is less than 20% of the maximum allowable pressure based on B31 rules for the largest size being tested, no action is necessary[1]. The following table gives that pressure based on B31.1 rules for Schedule 40 piping and is suitable for application to all B31 Code section piping systems.

More…

[1] B31.3, Table 323.2.2, note 3 exempts ordinary carbon steel from impact testing for temperatures below -20°F when the hoop stress is less than 30% of the allowable stress.

Maximum Hydrostatic Test Pressure below Which No Action is Necessary

Nominal Pipe Size	Maximum for Standard Weight	Maximum for Extra Strong		**Nominal Pipe Size**	Maximum for Standard Weight	Maximum for Extra Strong
1/4"	1101	1559		**10"**	208	288
3/8"	891	1285		**12"**	180	241
1/2"	854	1194		**14"**	163	219
3/4"	697	978		**16"**	143	191
1"	651	900		**18"**	127	170
1 1/4"	536	749		**20"**	114	152
1 1/2"	483	680		**22"**	103	138
2"	407	587		**24"**	95	127
2 1/2"	445	616		**26"**	87	117
3"	386	546		**30"**	75	101
3 1/2"	352	504		**34"**	67	89
4"	327	473		**36"**	63	84
5"	287	423		**42"**	54	72
6"	261	409		**48"**	47	63
8"	229	362				

If the hydrostatic test pressure is greater than shown above and you can heat the fluid used during hydrostatic testing above 90°F, no further action is necessary. If that is not possible, when ordering the following materials:

- A105 flanges
- A234 seamless carbon steel fittings, Grades WPA, WPB and WPC
- A53 seamless pipe, all grades
- A106 pipe, all grades

the purchase order should require material test reports to be provided and it should specify the following:

"The ratio of manganese to carbon shall be 5 or higher and the grain size shall be 7 or finer[2]"

Smart contractors will always use this last option since left-over material may end up on a higher-pressure job.

[2] Grain size number gets larger as grain size gets smaller, so a grain size of 8, 9, 10, etc. would be acceptable.

In closing, this is a great example of where participating in Code committee activities gives those who attend an inside line on what is going on in the industry that we can share with our membership. Contractors are encouraged to identify young individuals who can keep this practice going since those who participate today will not be doing this forever.

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Questions? Need more information?
Contact Dariush (Nick) Nikpourfard at 301-990-2211 or nnikpourfard@mcaa.org.

