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The Decision of the P Grades: How are different grades selected from the same SA335/A335 chrome moly specified material?

Sounds like a simple question to answer, but it is not. Let's start with the basics.

ASME SA335 / ASTM A335, Chrome-Moly pipe is a seamless ferritic Alloy-Steel Pipe produced in nominal or minimum wall thickness for high temperature service. Pipe ordered to this specification shall be suitable for bending, flanging, similar forming operations and for fusion welding.

Chrome Moly products are named so due to the presence of the two elements Chromium (Cr) and Molybdenum (Mo). Cr increases the material's resistance to corrosion and oxidation, and raises the material's strength at high temperatures. Mo is known to increase tensile and creep strength at high temperatures, reduces brittleness, and improves hardenability.

Sometimes referred to as "P Grade" materials or simply "Chrome", chrome moly pipe comes in more than 17 grades with the most widely used P-Grades being P5, P9, P11, P22 and P91.

It is commonly known that SA335/A335 material is extensively used in a variety of plants & processes across the globe including refineries, power plants, petro-chemical plants, hydrocrackers, cokers, high and super high temperature lines, reheat lines, distillation, oil field services, etc. In general, the most commonly used P grades in refineries are P5 & P9. The most commonly used P grades in the power generation industry and petro-chemical plants are P11, P22 & P91. A quick perusal, however, of what appears to be similarly designed facilities will result in findings that they do not necessarily use the same piping specifications. For example, there are many different designs and piping systems in what be generically called a "natural gas processing plant".

The ASME Code has issued guidelines on boiler and power piping design, manufacturing and fabrication, but there is no hard and fast rule for which grade applies when and where.

Within the ASTM standards, let's compare the titles of both the A106B and A335 specifications. The A106 specification is entitled "Seamless Carbon Steel Pipe for High-Temperature Service" and the A335 specification is entitled "Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service". So let's explore why ever one would select or prefer chrome moly over carbon (or vice-versa) and if it is chrome moly, which grades are then decided upon?

Modern power boilers can operate at over 5,000psi and at temperatures greater than 1,000 degrees Fahrenheit. ASME Section II contains tables of all the approved grades (like SA106) and what is the allowable design stress at elevated temperatures for various applications. SA106 Gr. B tops out at 1,000 degrees Fahrenheit and at those high temperatures it has little strength. So what is a designer to do when high temperature or high pressure needs are designed in but heavier walls are out of the question? Enter the possibility of using SA335/A335 — chrome moly pipe.

As the Cr (chrome) and Mo (moly) content are increased in the steel, the allowable stress at higher temperature is increased dramatically. The more Cr and Mo added (to a point), the stronger the steel will be. So a designer can decide, for example, do I want to use a stronger material like P91 (9% Cr, 1% Mo and additional alloying elements) with a thinner wall - or do I use a thicker wall pipe of lower strength like P22 (2.3% Cr & 1% Mo) or even P11 (1.25% Cr & .55% Mo)?

According to the A335 standard, the selection "will depend upon design, service conditions, mechanical properties and high temperature characteristics". While generally speaking the benefits of alloy steel pipe include its tensile strength, yield strength, fatigue resistance, toughness and wear resistance, it is as discussed earlier intended for high-temperature service and be suitable for various processes.

It is also worth noting that the SA335/A335 specification contains about 10 pages of information reflecting the differing requirements between the chrome moly grades.

It takes a critical reading and understanding of the nuances of a specification to truly understand it.

Each grade recognized under the specification can have differing requirements making for a large variety of choices as the operating environment and fluids running through the line may cover a gambit of erosion/corrosion, pressure, corrosion and temperature variances. Furthermore, chemical compositional differences between different grades that affect their physical properties (e.g., strength) are another factor to comprehend. Physical properties of strength and the upper temperature limits are a result of the increased chromium and molybdenum components mentioned above.

Ok, so that's a lot of information, but where do we stand in answering the question? Basically there are a throng of variables to consider and the answer resides entirely with the designer or design engineer to make the selection of the material and grade based on their design calculation outputs.

Many of the top questions design engineers need to consider to help them determine which P grade to select are:

a) Physical properties of strength, b) Upper temperature limits, c) Allowable stress, d) Thermal fatigue and number of operating cycles, e) Number of and configuration of loops and bends, f) Resistance to creep, g) Compatibility resistance to creep, h) The selection of parts to be welded, i) welding procedures, welding quality assurance and welding filler materials i) Hardness measurements, j) Pre heat temperatures and post weld heat treatment temperatures k) Other significant variables include temperature of water or steam, pH, oxygen content of fluid, quality of steam, flow velocity, quality of oxide layer on inner surface of the pipe and chemical composition l) Fabrication time & costs m) Weight considerations including pipe supports, n) Variety in the bill of materials — as steam proceeds through the turbine and piping systems, the temperature and pressure decrease. This allows the designer to use thinner walls — or lower grades — of pipe in different areas of the plant, o) Availability & cost differentials between different grades; it generally makes more sense to select an upgraded material when the upper margins of a range come into play.

The decision of which P grade is not a simple one and rests solely on the shoulders of the design engineers; hats off to them because, as one can clearly see, their jobs are complicated and critical to the success of multi-million dollar decision-making.