

How does a designer decide on the pipe wall thickness/schedule?

The first thing the designer will do is calculate the required wall thickness. He/she will then compare this with the minimum wall thickness for a standard pipe schedule. If he/she can't find a perfect match, which is often the case, he/she will select the next pipe schedule up; so the minimum wall thickness for the schedule is greater than the minimum wall thickness required by the design. Sometimes when the required wall thickness is very big or there isn't a suitable schedule covering it, the designer will specify pipe as "minimum-wall". Where this is the case, it is up to the manufacturer to decide on the nominal wall thickness so that the pipe wall thickness is guaranteed to be equal to or greater than the minimum wall thickness required by the designer.

What determines the required pipe wall thickness? The pipe wall thickness is primarily a function of the internal design pressure and temperature. For pipework in 'normal' fluid service, the required pipe wall thickness for straight pipe can be calculated using the following equation taken from ASME B31.3:

Where:

t = the required design thickness for pressure containment, mm;

P = the internal design pressure, MPa;

D_o = the outside diameter of the pipe, mm;

S = the allowable stress, MPa;

E = the quality factor;

W = the longitudinal weld joint factor;

Y = the temperature factor.

It is normal to add a corrosion/erosion allowance, particularly in the case of carbon steel. This would usually be calculated based on the predicted corrosion/erosion rate. If the pipe ends are threaded, it is necessary to include a mechanical allowance based on the thread or groove depth. These additional allowances need to be taken into account when establishing the actual required minimum thickness of the pipe, t_m , i.e:

$$t_m = t + c$$

Where:

c = the sum of the mechanical allowances plus the corrosion/erosion allowance, mm.

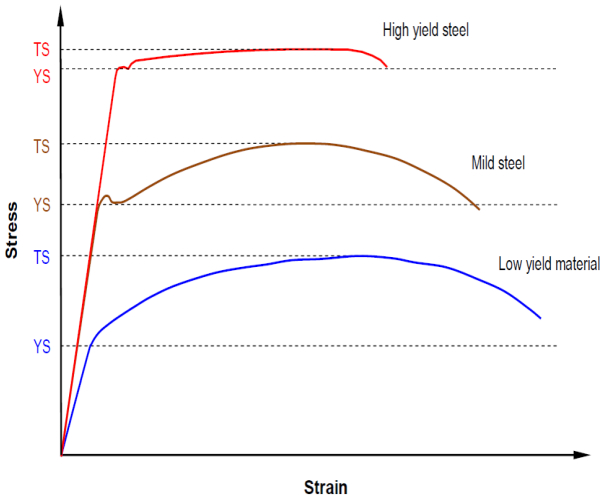
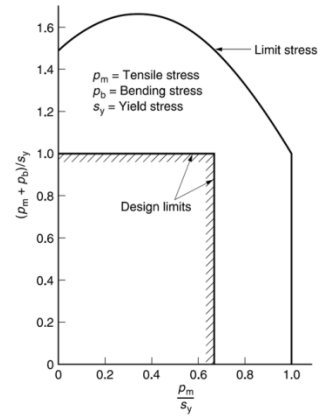
What determines the allowable stress? For a listed material, the allowable stress can be found in ASME B31.3 Table A-1. If the material is not listed in ASME B31.3 Table A-1, the allowable stress has to be calculated. The basic allowable stress value for materials other than bolting materials, cast iron and malleable iron are generally based on the lower of one-third of the tensile strength at temperature and two-thirds of the yield strength at temperature.

Why is temperature important? Temperature is important, because as it goes up the strength of the material goes down; so the allowable stress changes with temperature. If the pressure is not constant over the range of temperatures at which the pipe is going to operate, it is necessary to calculate the minimum required wall thickness at a number of different pressures and temperatures. The biggest value for the pipe wall thickness will be the one used in the design.

Why use an allowable stress and not simply the yield stress? Materials are not perfect and a system can be exposed to unexpected loads. Using an allowable stress ensures the design is much safer than it would be if the wall thickness was calculated based on the limit stress. The

diagram opposite shows that, even in the worst case situation where the allowable stress is based on two-thirds of the yield strength, in theory there is still 50% redundancy in the pipe even if the mechanical properties are lower than the test results would lead you to believe.

What normally governs the allowable stress and why? In almost all cases, it is the tensile strength of the material that dictates the allowable stress. The reason for considering the tensile strength is again one of safety; a low yield to tensile strength ratio is generally considered to provide a high capacity for plastic deformation and hence a bigger safety margin against fracture. A consequence of this is that ASME B31.3 positively discriminates against the use of high yield materials (e.g. API 5L Grade X52, X60, X65, etc.)



5L Grade X65 450 535 178

Material Grade	Yield Strength (MPa)	Tensile Strength (MPa)	Allowable Stress (MPa)
A333 Grade 6	240	415	138
5L Grade X52	360	460	153
5L Grade X60	415	520	173

Why do you need the quality factor, E , if you have the allowable stress? This provides additional safeguards against a potential failure of the pipe due to a flaw in its manufacture. There are basic quality factors that cover castings. In the case of pipe, fittings and flanges, it is unlikely that these would ever come into play, but the weld joint quality factor might. This applies in the case of welded pipes (and fittings) and takes into consideration the nature and extent of any non-destructive testing carried out on the pipe during its manufacture. The basic quality factors for longitudinal weld joints in pipes, tubes and fittings are specified in ASME B31.3 Table A-1B. It is interesting to note that, in the case of API 5L fusion welded pipe, even though the weld has been subject to 100% ultrasonic examination, the weld quality factor is 0.95. In order to bring it up to 1.00, it is necessary to radiograph the complete weld.

So, if E is the weld joint quality factor, what is W and why do we need it? W is the weld joint strength reduction factor. This takes into account the fact that, at elevated temperatures (i.e. above 427°C), the long-term strength of weld joints may be lower than the long-term strength of the base material. For the majority of applications, W will be equal to 1.00.

So, if we have W that takes into account the temperature at which the pipe is operating, why do we also need Y ? Y is used to address the increased ductility of piping materials as the temperature increases. The value of Y was originally 0.5. This was reduced to 0.4, which tends to be the value normally used to calculate the wall thickness of process piping. However, in the case of pipework operating above 482°C, it was considered that using a value of 0.4 would result in excessively thick pipework, which would lead to unnecessarily heavy and costly pipe, less flexibility to absorb thermal expansion and larger through-wall thermal gradients. To avoid these difficulties, and based on the results of burst tests, it was decided that between 482°C and 621°C the 0.4 factor would be gradually increased to 0.7. This is the basis for Table 304.1.1 in ASME B31.3.