Comments on the Allowable Stresses in B31.1 and SC III NC/ND-3600 (Revised June 2004)

Following preceding Code Cases the 2002 Edition of the Boiler and Pressure Vessel Code (BPVC) changed the allowable stress bases for some of the “design by rule” codes (Section I and Section VIII, Division 1) from the lesser of 1/4 of the tensile strengths or 2/3 of the yield strengths at temperature to 1/3.5 of the tensile strengths or 2/3 of the yield strengths at temperature. Both B31.1, by Code Case 173, and Section III, Subsections NC and ND have since conformed to the BPVC changes. There has been considerable discussion about the effect of these changes on piping design, with considerable misunderstanding as well. The following comments are offered to help in understanding the real effects of the proposed change.

Note, the change only reduces the factor of safety against the material tensile strengths, not yield strengths. The proposed change for piping, then, will reduce the pipe wall thicknesses a bit. This reduction will primarily affect piping designed for lower pressures and temperatures, e.g., below 700 degF. Piping failures due to internal pressure (burst) correlate best with material tensile strengths.

Regarding cyclic effects, since the 1950's, based on shakedown concepts, B31.1 has limited piping stress ranges due to thermal expansion (and other fatigue producing loads) to something less than 2 S(y). According to Markl (Reference 1), S(A) + S(L), which he equates to1.25 (S(c) + S(h)) in the rules proposed for B31.1 - 1955 edition, "utilize at most 78 percent of the available stress range S(av)", S(av) being equal to 2 S(y) which was "considered the maximum stress range... to which a system could be subjected without producing flow [yielding] at either limit", i.e., a piping system subjected to 100 percent shakedown. [Note: the scope of the B31.1 - 1955 edition included all pressure piping, i.e. the present B31.1, B31.3, etc. However, the pipeline codes have never embraced shakedown concepts because the pipeline grade materials were, until recently, not adequately tough.]

In the 1980's, the allowable stress basis for B31.1 (and BPVC SC I, SC III Class 2/3, and SC VIII Div.1, all) changed from the lesser of 1/4 tensile or 5/8 of yield to the lesser of 1/4 tensile or 2/3 of yield. This increased maximum S(A) + S(L) values in some cases, but did not exceed “78 percent of the available stress range” for those materials which were controlled by tensile stresses or 83 percent of the available stress range for those materials which were controlled by yield stresses, (1.25)(2)(5/8) = 1.56/2 = 0.78 vs. (1.25)(2)(2/3) = 1.67/2 = 0.83.

For the allowable stress basis change introduced, for seamless Grade B carbon steel operating at ambient temperatures, the current change will increase the maximum possible S(A) + S(L) value from 37,500 psi to 42,800 psi, but this is still a good deal less than (0.78)(2)S(y)= (0.78)(2)(35,000) = 54,600 psi. For seamless Type 304 stainless steel at operating ambient temperatures, the current change will increase the maximum possible S(A) + S(L) value from 47,000 psi to 50,000 psi. This, on the other hand, is equal to but not greater than (0.83)(2)S(y) = (0.83)(2)(30,000) = 50,000 psi. [Note: Obviously the S(A) values available for thermal expansion (and other fatigue producing loads) will be less than the maximum possible S(A) + S(L) values because of the existence of the S(L) term, either on the right side of the thermal expansion (fatigue) equation (13) in B31.1 or on the left side of the equation (11) in NC/ND-3653.2.]

Thus, while affecting the wall thickness required for pressure design, the proposed change cannot ever increase allowable stress ranges above the traditional 2 S(y) limit, which is the current basis for shakedown concepts in ASME B31.1 and SC III NC/ND-3600.

Reference 1: A.R.C. Markl, "Piping-Flexibility Analysis", American Society of Mechanical Engineers Paper 53-A-51