NASA TECH BRIEF

*Marshall Space Flight Center*



# Method for Determining Failure Potential of Pressure Vessels

## The problem:

Surface cracks in thin-walled pressure vessels may grow during testing, storage, and service. Depending upon the crack dimensions and associated stresses, the vessel may leak or even burst during pressurization. In the past, failures of this type have been largely avoided by one or a combination of the following means: (1) constructing the vessel of crack-resistant materials; (2) applying large safety factors to the calculated design loads or stresses; or (3) carefully inspecting the vessel for cracks and similar surface flaws at various stages of construction and service. However, structural material that has the required strength, stiffness, and density may not be crack-resistant; limitations of weight, construction, or cost may preclude the application of adequate safety factors; and complete periodic inspection of the vessel may not be feasible where vessel inaccessibility or where the cost and time required for inspection are factors.

## The solution:

Formulas have been derived to provide a quantitative estimation of the critical vessel wall and crack parameters that must not be exceeded to ensure against failure of pressurized vessels.

## How it's done:

For an existing pressure vessel of known dimensions and material, the maximum stress (pressure) that can be withstood by the vessel with small probability of bursting is given by

$$\sigma = \frac{\phi}{\left(1.21\pi\frac{B}{K_{1c}^2} + \frac{0.212}{F_{ty}^2}\right)^{1/2}} \qquad (1)$$

where $K_{1c}$ = plane-strain fracture toughness
$K_c$ = plane-stress fracture toughness
$F_{ty}$ = tensile yield strength
$\phi = 1 + 4.593\,(B/2c)^{1.65}$ (1a)
2c = length of the surface crack
B = wall thickness of the pressure vessel; depth of crack at penetration

All values of the material parameters designated in equation (1) must be measured on reference material as nearly identical (in composition, method of manufacture, and thickness) as possible to the material used in constructing the pressure vessel being evaluated. These values must be measured under conditions similar to those that would actually be experienced by the vessel.

If the length of the surface crack at the moment of penetration does not exceed a critical length, $L_c$, then further growth of the crack may be inhibited. The critical length is given by

$$L_c = \left(\frac{K_c^2}{\pi}\right)\left(2\sigma_0^2 - \frac{1}{F_{ty}^2}\right) \qquad (2)$$

where $\sigma_0$ = tensile stress in the vessel wall. The value of $\sigma_0$ may be determined to a high degree of approximation by the following iteration: A conservative (low) estimate of $\sigma$ is computed from equation (1) by assuming an infinitely long crack, for which $\phi$ is 1.00. This initial estimate of $\sigma$ is substituted for $\sigma_0$ in equation (2) which is then solved for $L_c$. This value of $L_c$ is substituted for 2c in equation (1a), and the value of $\phi$ computed from this equation is used in equation (1) for another computation of $\sigma$. The latter is again substituted for $\sigma_0$ in equation (2), and the process is repeated until the difference between the last and immediately

(continued overleaf)

preceding computed values of $L_c$ is considered negligible.

## Note:

Requests for further information may be directed to:

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## Patent status:

No patent action is contemplated by NASA.

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