

Modified Thin Wall Pipe Formula for Deep Water Application

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ABSTRACT

The effect of hydrostatic head on deep water pipelines is not negligible because the effect of external hydrostatic pressure increases as the water depth increases. Some pipe wall thickness determination formulas provided by federal regulations (DOI and DOT) do not account for the effect of the hydrostatic head. In some deep water cases, where the pipe is governed by the high internal pressure, these conservative formulas require unreasonably thick walls by neglecting the benefit of the external pressure.

ASME B31.4/B31.8 and API 1111 consider the effect of the external pressure in the pipe wall thickness calculation. The formula uses the thin wall pipe theory subtracting the external pressure from the internal design pressure. However, as the external pressure increases, the hoop stresses from this equation become too high compared to the thick wall pipe theory which provides exact solutions. The erroneous results from the thin wall pipe formula for deep water application inspired the author to find a better solution which is as accurate as the exact formula (thick wall formula) and as easy to use as the thin wall pipe formula.

In this paper, the thick wall pipe formula and the thin wall pipe formula are evaluated and compared in detail. Based on the evaluation, a reliable and easily usable formula is proposed in the end of the paper.

KEY WORDS: Deep Water, Pipeline, Pipe, Wall Thickness, Design Pressure, External pressure, Hoop Stress

NOMENCLATURES

a	Pipe inside radius
b	Pipe outside radius
D	Pipe outside diameter
Di	Pipe inside diameter
E	Longitudinal weld joint factor
F	Design factor

Pi	Internal design pressure
Po	External pressure
Pr	Pressure differential ratio = $(P_i - P_o) / P_i$
r	Pipe radius at any points along the pipe wall thickness
S	Pipe minimum specified yield strength
T	Temperature derating factor
t	Pipe nominal wall thickness
σ_h	Hoop stress = circumferential stress = tangential stress from exact solution (thick wall pipe formula)
σ_h'	Hoop stress from the thin wall pipe formula without considering external pressure
σ_{hm}	Hoop stress from the modified thin wall pipe formula
σ_{ho}	Hoop stress from the original thin wall pipe formula
σ_r	Radial stress

INTRODUCTION

For marine pipelines exposed to high hydrostatic head due to deep water, the role of the external pressure should be considered in pipe wall thickness determination. However, some of the industry codes used in the Gulf of Mexico do not consider external pressure, requiring unnecessarily thick wall pipe in deep water. Even when the external pressure is considered in the other Gulf of Mexico codes, these codes overestimates the wall thickness for high external pressure.

This paper points out what is wrong with the existing pipe wall thickness determination formula (original thin wall pipe formula) and proposes an improved formula (modified thin wall pipe formula) to predict the pipe wall thickness more accurately. The accuracy of the original thin wall pipe formula and the modified thin wall pipe formula, compared to the thick wall pipe formula, are presented for various D/t and $(P_i - P_o)/P_i$ ratios.

EXISTING PIPE WALL THICKNESS DETERMINATION FORMULAS

The internally and/or externally pressurized pipe wall must be designed for installation, hydrotest, and operation. In some cases, the pipe wall thickness may be governed by internal design pressure or