

Stress analysis methods for underground pipe lines

Elements include pipe movement, anchorage force, lateral soil force, soil friction, soil-pipe interaction

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ANALYZING an underground pipe line is quite different from analyzing plant piping. Special problems are involved because of the unique characteristics of a pipe line, code requirements and techniques required in analysis. Elements of analysis include pipe movement, anchorage force, soil friction, lateral soil force and soil-pipe interaction.

Unique characteristics. To appreciate pipe code requirements and visualize problems involved in pipe line stress analysis, it is necessary to first distinguish a pipe line from plant piping. Unique characteristics of a pipe line include:

- **High allowable stress.** A pipe line has a rather simple shape. It is circular and very often runs several miles before making a turn. Therefore, the stresses calculated are all based on simple static equilibrium formulas which are very reliable. Since stresses produced are predictable, allowable stress used is considerably higher than that used in plant piping.
- **High yield strength pipe.** To raise the allowable, the first obstacle is yield strength. Although a pipe line operating beyond yield strength may not create structural integrity problems, it may cause undesirable excessive deformation and possibility of strain follow up. Therefore, high test line pipe with a very high yield to ultimate strength ratio is normally used in pipe line construction. Yield strength in some pipe can be as high as 80 percent of ultimate strength. All allowable stresses are based only on yield strength.

- **High pressure elongation.** Movement of a pipe line is normally due to expansion of a very long line at low temperature difference. Pressure elongation, negligible in plant piping, contributes much of the total movement and must be included in the analysis.

- **Soil-pipe interaction.** The main portion of a pipe line is buried underground. Any pipe movement has to overcome soil force, which can be divided into two categories: Friction force created from sliding and pressure force resulting from pushing. The major task of pipe line analysis is to investigate soil-pipe interaction—which has never been a subject in plant piping analysis.

Code requirements. Pipe lines normally are designed, constructed, inspected and operated according to minimum federal safety standards stipulated in Title 49 of Code of Federal Regulations.^{1,2} The standards base for the analysis are ANSI B31.4, "Liquid Petroleum Transportation Piping Systems,"³ and ANSI B31.8, "Gas Transmission and Distribution Piping Systems."⁴

Because it is more economical to ship gas at the lowest temperature possible, the stress problem involved in a gas line is less severe than that in an oil line. The following discussion will be based mainly on ANSI B31.4 which is made a part of 49-CFR Part 195, but the philosophy presented should be applicable to gas pipe lines as well. This section covers only the rules that are pertinent to stress analysis, however, and requirements are revised frequently to reflect results of new developments.

Wall thickness. The first step in stress analysis is to calculate wall thickness required. (The diameter of the pipe is generally determined by a different discipline of engineering.)

According to the code, nominal wall thickness of straight sections of steel pipe shall be equal to or greater than t determined in accordance with the following equation:

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Table of Contents How To Do Stress Analysis Manual Calculations

1. Understanding the eBook How To Do Stress Analysis Manual Calculations
 - The Rise of Digital Reading How To Do Stress Analysis Manual Calculations
 - Advantages of eBooks Over Traditional Books
2. Identifying How To Do Stress Analysis Manual Calculations
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an How To Do Stress Analysis Manual Calculations
 - User-Friendly Interface
4. Exploring eBook Recommendations from How To Do Stress Analysis Manual Calculations

- Personalized Recommendations
- How To Do Stress Analysis Manual Calculations User Reviews and Ratings
- How To Do Stress Analysis Manual Calculations and Bestseller Lists
- 5. Accessing How To Do Stress Analysis Manual Calculations Free and Paid eBooks
 - How To Do Stress Analysis Manual Calculations Public Domain eBooks
 - How To Do Stress Analysis Manual Calculations eBook Subscription Services
 - How To Do Stress Analysis Manual Calculations Budget-Friendly Options
- 6. Navigating How To Do Stress Analysis Manual Calculations eBook Formats
 - ePub, PDF, MOBI, and More
 - How To Do Stress Analysis Manual Calculations Compatibility with Devices
 - How To Do Stress Analysis Manual Calculations Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of How To Do Stress Analysis Manual Calculations
 - Highlighting and Note-Taking How To Do Stress Analysis Manual Calculations
 - Interactive Elements How To Do Stress Analysis Manual Calculations
- 8. Staying Engaged with How To Do Stress Analysis Manual Calculations
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers How To Do Stress Analysis Manual Calculations
- 9. Balancing eBooks and Physical Books How To Do Stress Analysis Manual Calculations
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection How To Do Stress Analysis Manual Calculations
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine How To Do Stress Analysis Manual Calculations
 - Setting Reading Goals How To Do Stress Analysis Manual Calculations
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of How To Do Stress Analysis Manual Calculations

- Fact-Checking eBook Content of How To Do Stress Analysis Manual Calculations
- Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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