1 Introduction

This thesis is written for multiple audiences. The immediate audience is E. I. DuPont De Nemours and Company in Wilmington, Delaware. The secondary audiences are my advisors Dr. Larry D. Mitchell, Dr. Robert West, and Dr. Alan Kornhauser. The final audience includes the practicing engineer that finds the need to comply with the ASME Unfired Boiler and Pressure Vessel standards and codes and the B31.3 Power Piping standards and codes. The purpose of this major document is to show the updated procedures and revisions to a computer program called *Tmin*. This program is used as a screening tool for determining the largest of the minimum pipe-wall thicknesses in a piping system. As piping ages in industrial plants the piping walls thin by corrosion and erosion. Thus such piping requires monitoring to determine whether the various piping segments continue to be safe to utilize in the production facility.

1.1 Motivation of Project

Chemical industries of the world today use mazes of piping spans throughout their industrial plants. These piping spans often involve pumping systems that deliver high-pressure chemical fluids to their respective destinations. During this simple process, there are two major problems that lead to a shortened pipe life: internal pipe corrosion, internal pipe erosion, and pipe fatigue. The source of the first problem is the corrosive chemicals that are involved and the corrosive properties of these chemicals when interacting with the piping materials at operational temperatures. As a result, piping systems have potential internal chemical corrosion that could thin the piping walls.

The second source of a shortened pipe life is erosion. The piping system may experience erosion because of the constantly moving fluid traveling rapidly through the pipes. In other cases the traveling fluid could be an abrasive slurry and could mechanically abrade the piping wall.

Tmin is used to verify that the pipe-wall thickness values of a particular piping span are within a safety limit. The safety limit thickness of the pipe can be verified through fundamental equations using the material properties of the pipes, piping dimensions, piping external/internal load, piping pressures, and piping geometry. The tedious process that is used to extract the safe thickness of these piping systems can be time consuming. Therefore, to lower time for final analysis, the *Tmin* computer program was modified to simplify analysis of vertical piping spans.

This computer program was written in Visual Basic and is called *Tmin*. Dupont has claimed proprietary rights to *Tmin*. In addition, to legally protect Dupont, the following warning appears during initial operation of *Tmin*, "This computer program is to be used for Dupont business purposes only. Use for any other reason must be specifically authorized. Unauthorized use will expose you to criminal and/or civil proceedings" [1]. One of the main inclusions to the update of *Tmin* is that Dupont requested future versions to include 2-Dimensional piping span, since the current version includes only 2-D horizontal piping span configurations.

The American Society of Mechanical Engineers includes thermal expansion calculations within its standards and codes [2]. Also listed in the Power Piping standards and codes are calculations for a combination thermal and cyclic pressurization [2]. *Tmin* does a calculation based on thermal expansion. However, *Tmin* does not incorporate calculation of thermal and cyclic pressurization of piping. As a result, this computer program should not be used in the evaluation of piping systems that may experience combinations of high-temperature and high-pressure differences between start-up and shut down of the system.

1.2 Original Computer Code of *Tmin*

The initial computer program developed by Dupont analyzed only 2-Dimensional horizontal sections of pipe. The end user of *Tmin* selects the piping material and piping configuration that corresponds to the actual installation. The 2-D horizontal piping span configurations is shown in Figures 1-1, 1-2, and 1-3. These piping spans include the following combinations: a variable length single pipe run with the option for a full-length straight pipe, two pipe runs connected by a pipe elbow in the middle, or three pipe runs connected in the middle by the use of a pipe “Tee.” However, all of these configurations are in a single horizontal plane. Each of the piping spans has its individual length. In these piping spans, a single additional force, which was interpreted as a valve weight, can be added anywhere along the piping system, if such a valve-pipe configuration exists.

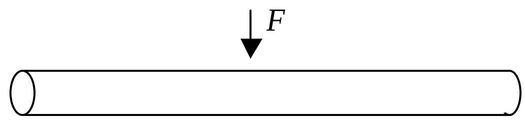

Figure 1-1. Full-Length Pipe Run with Additional Valve Force

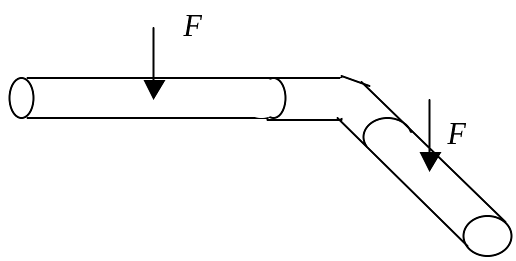

Figure 1-2. Two Pipe Runs with Addition of an Elbow and Valve Forces

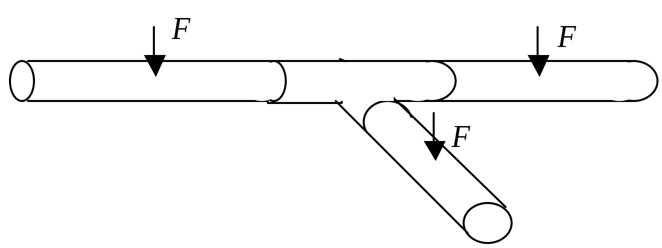

Figure 1-3. Three Separate Pipe Runs with Addition of Pipe Tee Section

For the last two cases, when an elbow or “Tee” configuration is chosen, *Tmin* adds a pre-determined stress intensity value (discussed in Chapter 4) corresponding to the piping material chosen and uses this value for final pipe wall thickness calculations. For each of these cases, torques and the induced torsional stresses are not calculated. The end result is a pipe wall thickness that may not be an accurate representation of the actual minimum pipe wall thickness attainable before the piping segment needs to be replaced. To ensure an accurate representation of the various minimum wall thicknesses of these piping configurations, recommended additions to include torque calculations are discussed in Chapter 7.

Once the end user chooses the pipe configuration in the program, several additional fields must be filled in. These additional fields include internal fluid temperature, pressure, and outside pipe insulation. Internally *Tmin* calculates insulation as a distributed load equal to 20 percent of pipe load, unless otherwise specified. In order to analyze these pipe configurations properly to calculate the minimum pipe-wall thickness, a series of equations are used. These equations are presented and discussed in later sections.

1.3 Scope of this Thesis: Modifications to *Tmin*

One of the issues that were faced in the updating of *Tmin* was the requirement to add fatigue data into the computer code. The following document titled: *ASME Boiler and Pressure Vessel Code* [3] includes standards and codes that were written by the American Society of Mechanical Engineers (ASME). The standards and codes written are required to be followed by law and are to be followed in order for safe working conditions to be maintained. Once the fatigue Stress-Life curves are implemented into the *Tmin* computer code and ensured that they followed the ASME standards and codes, other revisions of *Tmin* are to be completed. Other items to be included into *Tmin* are as follows:

- Stress analysis of a 2-D vertical piping span
- Output results to a Microsoft Word® document for ease of email transfer and printing
- Documentation revisions in the help files

1.4 Outline

This thesis is comprised of seven chapters. Chapter 2 discusses the literature survey that was used as background research. Chapter 3 includes the analysis of the theory of fatigue as applied to piping systems. Chapter 4 involves the analysis procedures used in *Tmin*. Chapter 5 contains the modifications that were introduced into *Tmin*. Chapter 6 includes benchmark or test cases of static pipe configurations that verify the correctness of the analysis procedures. Chapter 7 is the final chapter of this thesis; conclusions and recommendations are discussed here.