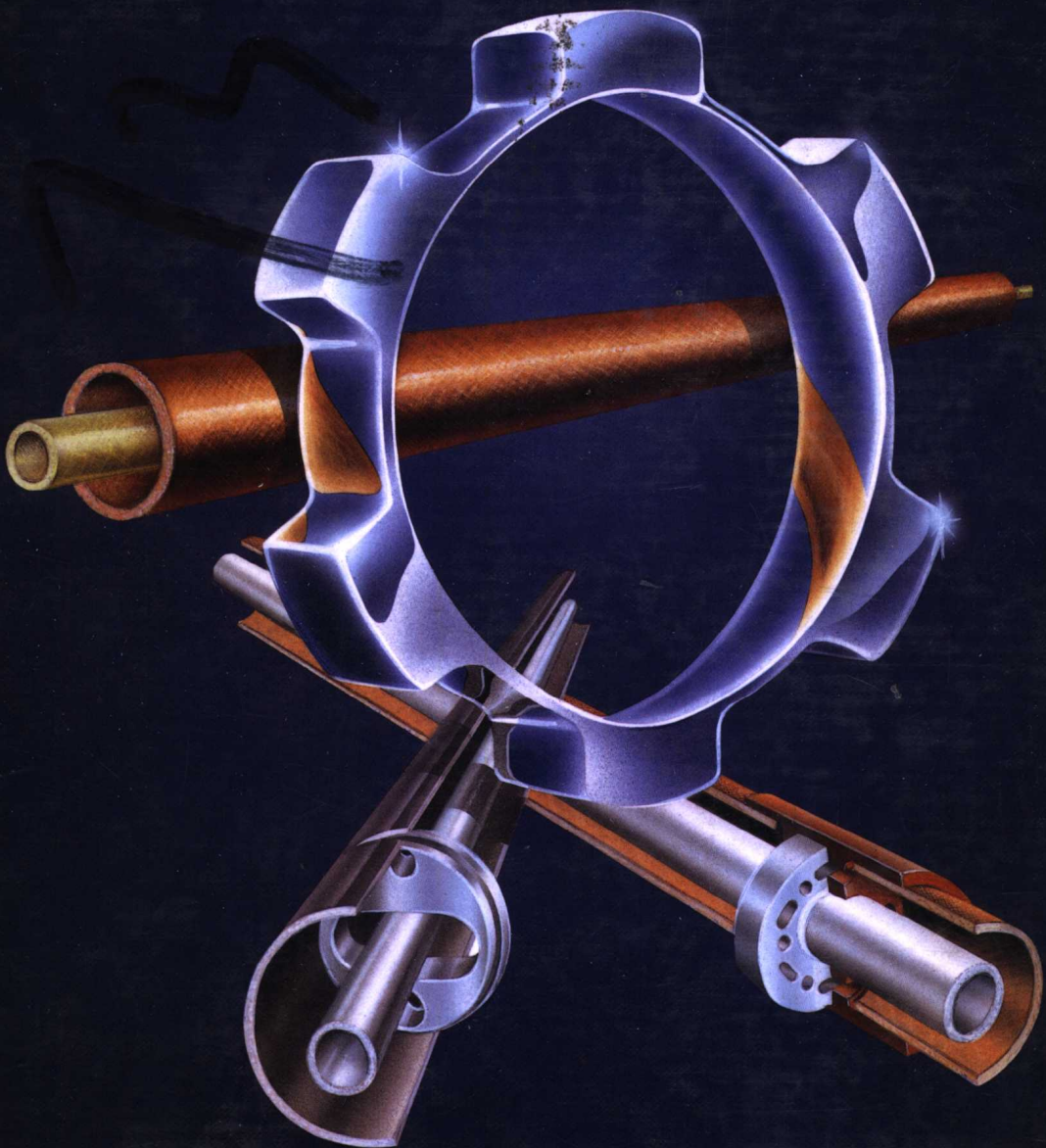

Handbook of Double Containment Piping Systems

Christopher G. Ziu



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Christopher G. Ziu, P.E.

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Preface

On December 23, 1988, a major law went into effect in the United States which has changed forever the way that industry views chemical and petroleum piping systems. This law, which was written as a revision to the Resource, Conservation and Recovery Act, requires that the majority of underground tanks and their associated pipes which are intended to store or transport petroleum fluids and/or chemical waste be provided with special means to prevent against leaks to the surrounding environment. With respect to piping systems, this now usually entails providing a separate outer pipe to house the inner pipe, so as to contain any leaks that may occur, and to provide a means to facilitate the detection of such leaks. We refer to such a system in this book as a double containment piping system.

To many, the thought of placing one pipe inside of another sounds like a relatively simple and straightforward task, and without much challenge involved. I can certainly be included among those who felt this way upon first considering this concept. However, as one gets involved in trying to design and implement such systems, one is soon overwhelmed with the enormous number of subtleties and complexities that arise. One can quickly be overwhelmed just by the task of even considering the sheer number of combinations of materials and systems types that exist for each and every design condition. The vast number of considerations and options that exist are quickly realized by examining the size of this handbook and the amount of information that is contained in it. This book reflects my ten years of study of and experience in dealing with this topic.

When I first started out on this project, I was aware of the challenge of incorporating the many types of material systems and their varying physical properties into one all-encompassing handbook. I have attempted to maintain a balance and neutrality with respect to the various materials considered. However, it is inevitable that some of my experiences with and preferences for certain materials have at times led to subjective coverage. It is my hope that the reader will bear this in mind, and keep an open mind with respect to material choices and system design options. It is my belief, and this is reflected in the text, that in any given application there is likely to be at least one suitable choice of metallic, RTRP (fiberglass), or thermoplastic material. The reader is encouraged to keep this in mind.

Chapter One presents a general introduction to the subject. It also provides information related to groundwater resources. Chapter Two covers material considerations, with particular emphasis on the three major classes of piping and tank materials: metallic, RTRP (fiberglass) and thermoplastic. The proper selection of materials is the first step in the process of designing a system. It is a step that can never be underestimated.

Chapter Three provides the reader with an understanding of when to use the various combinations of inner and outer material systems. It classifies system material combinations into 17 broad categories and attempts to point out major considerations and complications that each present. Chapter Four covers fluid dynamic considerations for both the inner and outer pipes. Fluid dynamics is the scientific basis by which piping systems are typically sized, at least initially. Ultimately the sizing of pipes involves economic factors, which is true for both primary and secondary containment pipe systems.

Chapters Five, Six and Seven present the considerations involved in designing each specific component of a primary piping system. The philosophy which is used in this text is clearly based upon that of the ASME B31.3 Chemical Plant and Petroleum Refinery Piping Code. It is the world's most widely used code for designing chemical and petroleum piping systems. It also governs the majority of double containment piping system applications in North America. The reader should be aware that not all systems are covered by the code. Other codes may apply (e.g., ASME BPV code, Section III, Div. 1, Subsections NB, NC and ND for Nuclear Piping, class 1, 2 and 3 components, respectively; ASME B31.1 for Power Piping; ASME B31.4 for "Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia, and Alcohols"), or the system may be outside the scope of a design code (e.g., certain gravity sewer systems, which may be governed by municipal building codes or plumbing codes).

Chapters Eight and Nine are important, covering in detail the topics of thermal expansion and structural criteria. The concepts here which apply to systems are interrelated to those concepts discussed in Chapters Five, Six and Seven for components. Chapter Ten discusses heat transfer theory, the concepts of which are applicable to double-walled piping systems of many types (e.g., jacketed process pipes, heat exchangers, insulated pipes, etc.).

Chapter Eleven provides the reader with an overview of the many layout options that exist for any given system design. The concepts discussed here are interrelated to those of several of the other chapters. In particular, thermal expansion calculations and considerations are affected anytime a layout change is made in a system. Chapters Twelve and Thirteen cover the fabrication, installation, inspection and testing considerations for systems of all types. Chapter Fourteen covers many details with respect to tanks, and the interacting of piping systems with tanks. This information is included since many double containment piping applications involve tanks.

Chapter Fifteen is very important. One of the main functions of a double containment piping system is to facilitate the detection of leaks. The early detection of leaks minimizes fluid loss, and allows for quick repair of the system and safe removal of leaked fluid. Leak detection options are presented and discussed for systems of all types, including piping and tanks of both single-wall and double-wall design.

Chapter Sixteen presents a discussion of some of the alternative means to provide secondary containment for piping and tanks. It also discusses some of the more novel approaches to repairing and retrofitting lines which are in place. It is in this area of system design that it is anticipated that many new approaches will be developed over the next few years.

It is my hope that this book will serve as the authoritative text on this subject for some time to come. It is expected that future editions of this text will be updated to include the many changes that are anticipated to occur in this continually developing area of technology.

Acknowledgments

There are many individuals and companies to whom I owe my gratitude for contributing in some way to the development of this text. Some were contributors in a direct manner (e.g., as editors), and others helped indirectly by contributing to the knowledge that I have gained over the years in piping, in nonmetallic materials (thermoplastic and RTRP), and in the art of double containment and leak detection. It is likely that I have left some names out inadvertently. However, I would like to offer my thanks to all of those individuals and organizations who lent support to me over the years by helping me to gain the knowledge that was necessary to write this text.

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Introduction

1.1 History of Double Containment Piping

The concept of placing a pipe within another pipe dates back to the early days of heat exchangers. Other related applications have also existed, including jacketed process piping systems and insulated utility and process piping equipped with external jacketing. Double-pipe heat exchangers were among the first types of heat exchangers used. The design of such systems has been considered as a relatively straightforward procedure in terms of heat exchanger design. Many of the design, construction, and fabrication techniques for double-pipe heat exchangers are the same as those required of double containment piping systems. The same is also true of jacketed process piping systems and insulated (and jacketed) pipes. Therefore, these related applications set some of the historical bases for successfully designing and implementing a double containment piping system. However, double containment piping systems tend to involve many unique and additional considerations in comparison to these systems. The main differences are due to the purpose of double containment piping, which is different from any of the other three applications mentioned; this is, to house a primary pipe for the purposes of preventing a corrosive, flammable, hazardous (including toxic and carcinogenic) or radioactive fluid from ever finding its way to the external atmosphere.

In accomplishing this purpose, it is best to design both the primary and secondary containment for mechanical integrity, while monitoring the containment (for possible breach of primary and secondary containment), and without adversely affecting flow capacity in the annulus (e.g., purging, flushing, draining, drying, and venting). As a result, these additional requirements of double containment piping result in many additional design and fabrication considerations beyond those of the related systems described in the preceding.

Up until the 1970s, dual arrangements of piping systems utilizing a carrier pipe with a secondary piping providing containment for purposes of environmental protection or safety were limited to highly specialized applications. These involved rare applications in the nuclear, gas, or chemical processing industry, where highly toxic or lethal chemicals or fluids were transported. The use of an outer jacket to maintain a positive seal around a primary carrier piping system and protect the primary piping was rare indeed until this time period.

In the 1970s, the world began focusing more attention on industrial pollution and its effect on our drinking water supply and air quality. In the United States, in particular, there were several incidents, such as the revealing of widespread pollution at Love Canal in upper New York State, that caused a public outcry and drew attention to the problem. In addition, there were several incidents of contamination caused by large electronic circuit manufacturers, electroplating manufacturers, chemical manufacturers, and similar industries that process hazardous chemicals. Also, many of the hundreds of thousands of underground storage tanks installed 20-50 years earlier had developed leakages due to soil corrosion. Contamination reports of drinking water supplies due to petroleum and their byproducts were becoming more and more frequent.

Several large U.S. electronics manufacturers began an unusual practice in the 1970s for their underground, and in some cases above-ground, hazardous chemical piping systems. Under the watchful eye of their respective local and state environmental agencies, they began placing their underground transportation piping within an outer jacket for the sole purpose of preventing any leakages from getting into the ground water supply. Part of the reason for doing so was due to inadequate performance on the part of ordinary single-wall piping components intended to handle these chemicals. Leakages from joints, failures of piping materials due to poor manufacture or installation practices, inappropriate material selection, and soil corrosion were some of the contributing factors. Thus began the modern day practice of placing underground piping systems within a secondary containment piping system for the sole purpose of protecting the local environment.

Unfortunately, many of these early systems met with complications that resulted in less-than-successful performance. The first attempts at dual arrangements met with frequent failure. This was primarily due to systems being designed with combinations of piping components whose geometries were not readily compatible. Also, there were technical issues that arose that had not been addressed in the design. This had to do with structural concerns (supporting and centering the inner system), differential thermal expansion issues, penetration sealing issues, and many others. Additionally, many of these systems were installed with poor fabrication techniques, resulting in installations that lacked inherent stability and were thus readily subject to premature failure. The lack of design consideration and installation deficiencies resulted in failures that manifested themselves in predictable ways. These included the separation of split outer pipe and split outer fittings, coupled with failed inner welds, thereby leading to a double failure. Other means of failure included premature failure of inner and outer pipes due to fatigue, excess strain, and many other reasons.

During this same time frame, the federal government of the United States was studying ways to protect against the failure of underground storage tanks and piping transportation systems. This resulted in revisions to the Resource Conservation and Recovery Act (RCRA) of 1976, which were enacted in 1984. Signed into law as the "Hazardous and Solid Waste Amendments of 1984" (U.S. Public Law 98-616, signed November 8, 1984), it extended and strengthened the Solid Waste Disposal Act, as originally amended by the Resource Conservation and Recovery Act of 1976. The amendments contained strict requirements and provisions for underground storage tank and piping systems.

For systems containing a hazardous fluid [according to the EPA as defined in the Code of Federal Regulations (CFR), Title 40, part 241] or petroleum-based product with 10% or more of its volume underground (including piping), the laws contained strict provisions.

The provisions gave the user a choice of providing secondary containment with leak detection or to use corrosion-resistant materials with frequent monitoring and tightness testing (petroleum-based products only). An alternative for petroleum piping applications involved the use of ordinary carbon steel (e.g., A-53 or A-106, Grade B) with some form of coating and cathodic protection added. In the case of the so-called hazardous chemicals, above-ground systems were regulated as well, unless the systems were to be inspected on a daily basis. The regulations applied to both new systems and existing systems. Existing systems were subjected to a retrofit requirement according to a time table, with the oldest systems being required to be replaced first. Thus, all existing systems in the United States (installed prior to December 1988) have been scheduled to be replaced within a 10-year time frame from the commencement of the regulations (by December 1998), by the strictest interpretations of the regulations, if they are not already in compliance. It is important to note that there are many aspects to the U.S. regulations (e.g., minimum volume requirements, regulated substances, leak detection requirements and options, etc.), and that the requirements and degree of enforcement vary according to individual state. Other countries beyond the United States are currently considering the development of similar regulations and are expected eventually to adopt them by the year 2000.

The 1984 amendments passed in the United States provide a framework by which individual states, territories, and possessions of the United States are mandated to draft state legislation, with their laws being at least as stringent as the U.S. Federal law. Enforcement is required at the individual state level, with the Federal Environmental Protection Agency overseeing each state program. Prior to the Federal laws being adopted in the United States, some of the individual states where ground water contamination has been a particularly bad problem, have adopted similar laws, prior to the Federal government requiring them to do so (e.g., California, New York, parts of Texas, and others).

A major incentive has existed since 1984 for inventive component suppliers to develop and market products that offer basic double containment features. Within a 5-year time frame from 1984, single-wall tank and pipe manufacturers recognized this need and began to develop and offer products that met the basic needs of the new regulations. What has become readily apparent, however, is that so-called "pre-engineered" double containment products are not enough. This is because each and every situation tends to be a unique one that requires some amount of custom design and fabrication. Requirements for custom design are even greater when piping or tank products are to be combined with some means of leak detection, as is true in the majority of applications. Therefore, it has become readily apparent that a coherent set of design and installation standards is needed in order to assist engineers and material suppliers in designing systems to work in a manner desired for each given application.

The idea for this text has grown from this recognized need. The book is an attempt to present a coherent set of design and installation standards. It is hoped that individual designers may apply these standards, together with a turnkey approach to each given potential design application. In doing so, a designer may solve many of the problems encountered early on, and result in high-quality, well-functioning double containment piping systems. In doing so, the possibility that piping and tank systems will contribute to future pollution of the earth and its atmosphere will be minimized to the greatest extent possible.

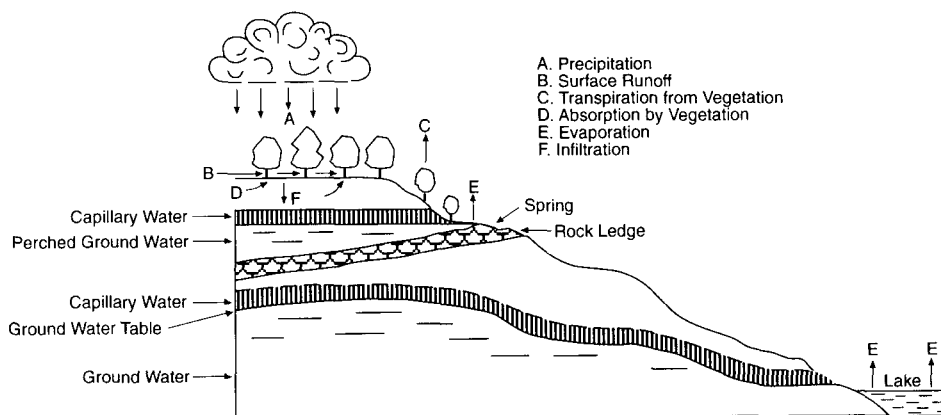


Figure 1.1. Normal hydrologic cycle. (Source: U.S. Army Corps of Engineers.)

1.2 Ground Water Technology and Ground Water Contamination

One of the main reasons to use a double containment piping system is to help preserve and protect the natural ground water supply from leaking chemicals. Therefore, it is important that the users and designers of piping systems gain a basic understanding of what ground water is and how the hydrologic cycle works. It is important that everyone involved in potential underground piping systems understands what it is, so that it may be realized exactly how important it is to prevent underground chemical leaks from occurring. Thus, an overview of ground water and the hydrologic cycle is essential in a handbook of this type to understand the full scope of double containment piping applications.

The term ground water is usually defined by geologists as any water found below the water table or in any geologic formation that is fully saturated. Subsurface water, on the other hand, is any near-surface water that infiltrates soil and is not absorbed into the ground at a lower level. Ground water and subsurface water are part of the normal hydrologic cycle, which is illustrated in Figure 1.1. Ground water in many locations is used to obtain a supply of drinking water. It also may flow by underground streams or rivers to replenish the supply of drinking water in lakes and other above-ground bodies of water.

Subsurface water is often thought of as more of a problem than a resource, as it often interferes with construction projects or causes damage to existing structures.¹ However, ground water and subsurface water are both important parts of an ecological cycle that helps to maintain the delicate balance of nature of all living things. Ground water storage represents the largest means of fresh water storage. Runoff-producing rains are not by themselves sufficient to reduce continuing outflow of streams and lakes during prolonged drought periods, which often follow periods of precipitation.

The relation between ground water and surface storage can best be described as mutual interdependence. The quantity of usable ground water storage distributed in structures is determined by means of precipitation, evapo-transpiration, geologic structure, and other minor contributing factors. There are two parts that make up the total quantity of ground water supply. The first derives from the hydrologic cycle, and the other consists of water trapped in past ages that is no longer naturally circulated in the cycle.

Water seepage to and from surface water sources, its movement to lower basins, and the amount of water transpiration that occurs in an undeveloped ground water basin depend upon the quantity of water in storage and its rate of recharge. Recharge may exceed discharge during periods following abundant rainfall. When recharge exceeds discharge, the excess rainfall increases the amount of water stored in ground water basins. As the pressure of artesian water rises, outflows increase as the gradient to points of discharge become steeper and steeper. Storage decreases from outflow causes water table levels and artesian pressures to decline as recharge no longer occurs. The major fluctuations in storage are seasonal in most undeveloped basins, and there is little change in the mean annual elevation of the water levels. The average annual inflow to storage is thus approximately equal to the average annual outflow, which is defined as the basin yield. An illustration of basic geologic formations is presented in Figure 1.2 to help understand this process.

Ground water distribution is normally divide into zones of aeration and saturation. When all of the voids are filled with water under hydrostatic pressure, it is referred to as the saturation zone. If the spaces are filled partly with air and partly with water, they are referred to as the aeration zone, and may be further subdivided into several subzones as follows:

1. **Soil/water zone:** The soil/water zone commences at the ground surface and travels downward through the major root zone. The total depth of this zone is dependent on vegetation and the type of soil, and is a variable quantity. For the most part, the zone is unsaturated, unless there is heavy infiltration. There are three major types of water that may be encountered in this region: (1) gravitational water, which is excess soil water draining through the soil; (2) capillary water, which is held by surface tension; and (3) hygroscopic water, which is adsorbed from air.

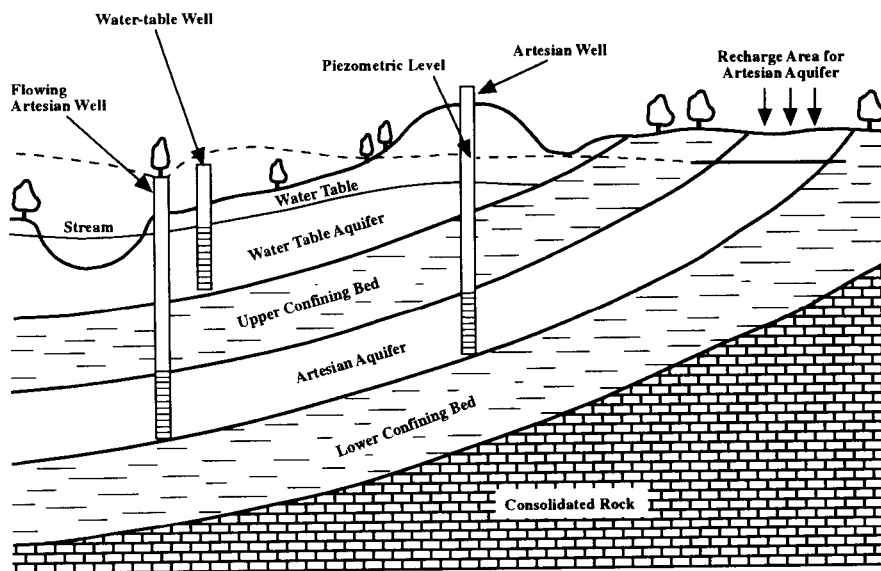


Figure 1.2. Illustration of basic geologic formations. (Source: Michael Frankel, "Sub-Surface Drainage: What is important to the Plumbing Engineer," *Plumbing Engineer*, 18(2), March 1990, pp. 26-32.)