NATIONAL COOPERATIVE
HIGHWAY RESEARCH PROGRAM REPORT **309**

PROTECTION OF PIPELINES THROUGH HIGHWAY ROADBEDS

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL

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PROTECTION OF PIPELINES THROUGH HIGHWAY ROADBEDS

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AREAS OF INTEREST:

Facilities Design
Maintenance
Soil Foundations
(Highway Transportation, Rail Transportation)

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C.
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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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FOREWORD

By Staff
Transportation Research Board

This report provides a summary of information on protection of pipeline crossings of highways and contains guidelines for use by highway officials in determining the desired type of protection for specific circumstances. These guidelines take into account factors such as pipe location and design, construction methods, required cover, consequences of failure, corrosion protection, and future highway widening and construction. The guidelines may be used to assist states in formulating policies on pipeline crossings. The report should be of interest to highway department personnel dealing with utilities and right-of-way, as well as to individuals with utility companies who must prepare requests for pipeline crossings.

Existing policies for pipeline protection are extremely varied. Many state highway and transportation agencies require that pipelines through highway roadbeds be encased. This policy is predicated on the expectation that as a result of encasement: (1) the pipeline is protected from associated loading; (2) in the event of pipeline rupture, liquids would be discharged out of the ends of the casing, protecting the integrity of the roadbed; and (3) ruptured pipelines could be conveniently removed from the casing and new pipe reinstalled. In other cases, improved pipe designs and strengths, together with the problems and costs of the use of casings with cathodic protection systems, lend support to the fact that encasement is not always the best alternative to pipeline protection.

No comprehensive national standards exist for underground pipeline protection for highway crossings or for conditions warranting encasement or nonencasement. In 1983 research was completed under NCHRP Project 20-7, Task 22, and a report was prepared entitled "Encasement of Pipelines Through Highway Roadbeds." That report documented the state of the art of pipeline encasement on a national basis. Although it is recognized that pipelines in highway right-of-way should be protected to a greater degree than normal "line" pipe, encasement is only one of several currently available means of providing increased protection.

The research conducted under NCHRP Project 15-9 and presented in this report includes a thorough review of the literature and information pertaining to pipeline crossings, updating that presented in the previously mentioned report. The review covers various state policies, AASHTO's publications, *A Guide for Accommodating Utilities Within Highway Right-of-Way* and *Policy on the Accommodation of Utilities on Freeway Rights-of-Way,* federal pipeline regulations, and policies developed by the pipeline industry. Pipeline failures are summarized.

Based on this research, guidelines for the protection of pipelines through highway roadbeds were developed and are presented. These guidelines are intended to assist highway officials in reviewing requests for approval of pipeline crossings of highways. Factors that need to be considered include:

- Location
- Method of construction
- Depth of cover
- Consequences of pipeline failure
- Corrosion
- Carrier pipe design
- Future highway widening and construction.

With these factors in mind, as well as the possible causes of failures, a matrix of protective measures, including encasement, is included. Each of these protective measures is discussed.

These guidelines can be adapted for local conditions by the various state highway departments to formulate or update policies governing pipeline crossings. Highway officials and utility industry personnel are cautioned that the guidelines are general in nature and based on evolving practice. Accordingly, each pipeline crossing should be treated and analyzed as a unique situation.

CONTENTS

ACKNOWLEDGMENTS

Wilbur Smith Associates, BTML Division, Consulting Engineers, located in Falls Church, Virginia, prepared this report under NCHRP Project 15-9. Principal Investigator for the project was Raymond A. Koenig, Jr., and the Assistant Investigator was John P. Taylor, P.E.

Many state transportation departments, utility company officials, staffs from government agencies at the federal and state level, trade associations and independent agencies contributed to the information included in this report. Because of the number of responses and the limited scope of the study, it was impossible to include data received from each source in the final report. Both to those who recognize their input directly in this report, and those who do not, gratitude is expressed.

Special acknowledgment is given to Mr. Frank E. Fulton, Chief, Pipeline Safety Enforcement Division, U.S. Department of Transportation, Mr. H. M. Shepherd, Petroleum Engineer, National Transportation Safety Board, Dr. T. D. O'Rourke, School of Civil and Environmental Engineering, Cornell University, Mr. V. A. Yarborough, Colonial Pipeline Company, and other utility and highway officials who contributed to this study.

PROTECTION OF PIPELINES THROUGH HIGHWAY ROADBEDS

SUMMARY

Utility accommodation policies for pipelines crossing highways have not changed significantly since the previous research of NCHRP Project 20-7, Task 22, "Encasement of Pipelines Through Highway Roadbeds," was prepared in March 1983. However, there does appear to be a growing awareness and acceptance of the fact that encasement of pipelines for highway crossings is not always the best alternative for providing protection for pipelines or highways. State highway agencies appear to be more amenable to allowing utility crossings of highways without encasement. Recent research on utility crossings of railroads has application to highway crossings in the use of alternatives to encased crossings. Recent catastrophic failures of pipelines at highway crossings highlight the potential problems of encased pipelines.

While these developments have been going on, there have been no guidelines available to assist highway agency personnel in the approval of proposed pipeline crossings of highways. This research project (NCHRP Project 15-9) has developed guidelines based on current practices and available information concerning pipeline crossings of highways. These guidelines will assist highway agency personnel in approving proposed pipeline crossings of highways by utilities. The factors that are presented for consideration in the guidelines are:

- Vertical and horizontal location of the pipe.
- Allowable construction methods.
- Required cover.
- An assessment of consequences of pipeline failure.
- Corrosion protection.
- Carrier pipe design.
- Future highway widening and construction.

The methods of providing additional protection are also discussed with suggestions for using appropriate protection methods in different circumstances.

CHAPTER ONE

INTRODUCTION AND RESEARCH APPROACH

THE PROBLEM

In 1981, research was conducted addressing the need for encasing pipelines under highways. The research was sponsored under NCHRP Project 20-7, Task 22, entitled "Encasement of Pipelines Through Highway Roadbeds" (*1*). The objective of that research was to develop procedures for determining the need for pipeline encasement at highway crossings based on:

(1) a review of literature on pipeline design and performance, (2) limited stress analyses of underground pipelines, and (3) an evaluation of field experience by highway, railroad, and utility agencies of encased and uncased pipelines.

The study was completed in 1982 and the final report accepted by NCHRP in 1983. The final report contained a review of existing regulations concerning pipeline crossings including those of the U.S. DOT Office of Pipeline Safety, and referenced 42 related publications in the bibliography. The report contained the results of a survey of state highway departments, utility companies, and pipeline operators regarding their encasement practices. This survey also revealed problems encountered with the use of casings, particularly with regard to cathodic protection systems. A discussion of warrants for providing increased protection at pipeline crossings was included in the report as well as procedures for limited stress analyses for design of both encased and uncased pipeline crossings.

The study concluded that pipelines in highway and railroad rights-of-way should be protected to a greater degree than normal "line" pipe. Encasement is only one of several currently available alternatives to provide such increased protection. Local conditions must be taken into account in selecting a protection method including the nature of the facility being crossed, the nature of the crossing pipeline, the nature of the soil through which the pipeline passes, population of areas immediately adjacent to the right-of-way, and impacts of pipeline failure.

The conclusions contained in the report also summarized the reasons or warrants for providing protection at a highway/pipeline crossing. The various methods of providing additional protection applicable to these warrants were discussed. Encasing or placing a sleeve was shown to be appropriate in some instances, but sleeves have not been successful in facilitating the removal of carrier pipe and can interfere with cathodic protection devices. The potential problems of cathodic protection and other causes of failure should be considered during design. The report stated "each crossing and protective method has its own unique considerations and limitations, all of which must be thoroughly evaluated for each crossing application."

Since the completion of the final report for NCHRP Project 20-7, Task 22, methods for protecting pipelines crossing highway rights-of-way have continued to receive attention. While the safety of the highway using public and utility owners is of paramount importance, the potential cost savings are great if certain installations can be made without encasement. Such issues as: the effectiveness of known corrosion protection; the lack of data on failure rates and the consequences of failures; unknown maintenance and installation costs; and the impact of the types of materials being transported have all been raised. These issues reveal the lack of accepted guidelines to follow in deciding if additional protection is necessary for a pipeline crossing a highway, and, if necessary, the kind of protection. The objective of NCHRP Project 15-9 is to develop guidelines for pipeline protection through roadbeds.

RESEARCH APPROACH

In order to accomplish the objective of this research project, the research was conducted in four phases or tasks: (1) further data collection for failure rates and maintenance costs; (2) the assessment of the consequences of failure on highway and utility activities; (3) the development of guidelines for selecting pipeline protection; and (4) the presentation of information in a summary report.

The following chapters and appendixes include findings, analysis of the problem, and conclusions related to the development of the guidelines for pipeline protection through highway roadbeds. The guidelines appear as Appendix A, entitled "Guidelines for the Protection of Pipelines Through Highway Roadbeds."

CHAPTER TWO

FINDINGS

BACKGROUND

Research conducted as part of NCHRP Project 20-7, Task 22, resulted in a large body of documents related to the encasement of pipelines crossing railroad and highway roadbeds. Those documents included state highway agency specifications and regulations, related research, and input from utility and industry groups. The documents were reviewed during the conduct of NCHRP Project 15-9. They provided the basis for further investigation and data gathering to meet the objective of this project, the development of guidelines for pipeline protection through roadbeds.

In particular, the previously collected information was reviewed for industry material and state regulations that may have been updated since 1982. States that had previously allowed uncased pipeline crossings were identified so that further information on the performance of uncased crossings could be requested, as well as, costs and changes in practices related to these crossings. Utility and industry groups that had provided invaluable information in Project 20-7, Task 22, were identified as potential sources for further or updated information. A brief literature search of the Transportation Research Information System (TRIS) database was conducted to ascertain if any recent research had been conducted related to pipeline crossings of highways.

Requests for information were sent to 13 states and responses were received from 9. One of two utility operators and five of nine industry groups responded to requests for information. Unsolicited information was received from another source in response to a notice concerning the project that appeared in *TR News* (*2*). Phone queries and interviews with the National Transportation Safety Board and the U.S. DOT Office of Pipeline Safety personnel were also conducted.

INFORMATION UPDATE

AASHTO and Federal pipeline safety information analyzed and reviewed in NCHRP Project 20-7, Task 22, was found to be unchanged. No revisions were planned for Federal standards governing transportation of gas and hazardous liquids contained in Title 49 of the Code of Federal Regulations (*3*).

The state transportation departments chosen from which to request additional information for this study were not randomly selected. Rather, states that had provided useful information in the previous study were again asked to provide information. These states generally have large networks of natural gas or petroleum transmission pipelines within their borders. These states thus have more experience with the problem of hazardous material pipelines crossing highways. State responses to requests for information included the following:

- Georgia responded to questions concerning the use of concrete-coated steel pipe crossings by stating that approximately 120 had been installed ranging in size from 10 in. to 36 in. with no known problems after almost 15 years of service. A potential problem for this method of protection was noted in that a field procedure would be needed to apply concrete coating if road widening occurred. For existing steel casings requiring road widening, split casings can be placed around the carrier and welded to the existing casing to provide a continuously encased crossing. Georgia permits all types of pipelines to be placed across highways without a casing when lines are placed by the open trench method ahead of highway construction. A savings of approximately $700,000 was realized for three major pipelines crossing I-675 near Atlanta using this procedure.
- Pennsylvania allows noncased crossings of utilities when certain conditions and precautions are satisfied. These conditions vary depending on the class of highway and the type of utility. Each pipeline crossing of a highway must be individually designed by the utility for that location and requires approval of the state DOT. An interesting requirement for various pipeline crossings without casing is that "an acceptable scheme for future repairs or replacement of the facility without open cutting of the pavement or shoulder" must be provided with the utility request for approval. The state has not encountered any problems with the noncased crossings that have been installed. These have only been in use a short period of time but because of the higher class or thicker pipe used, a life expectancy in excess of 100 years is anticipated. Noncased installations are noted as being less expensive than cased crossings and offer the advantage of being easier to relocate or adjust if the facility is affected by highway construction.
- Kentucky still permits unencased crossings and noted there have been more problems with encased pipelines, including three recent pipeline explosions at highway crossings.
- Mississippi was in the process of updating or revising Standard Operating Procedures related to utility crossings. When the Highway Department is constructing a highway across an existing transmission pipeline, the utility company is asked to consider placing a longitudinally reinforced concrete protective pad instead of placing split encasement around the existing pipe. Another alternative is to replace the existing pipe with a thicker wall pipe across the proposed highway. Figure A-9 from Appendix A is an example of a protective pad used in Mississippi for a pipeline crossing.

Table 1. Summary of reported pipeline crossing failures in Texas Highway Department districts.

Failures Occurring in Pipelines	Uncased	Cased
Number of Districts reporting	23	23
Number reporting failures	11	13
Type of failed lines		
Water	5	1
Water and Oil	3	1
Oil	2	4
Aviation Fuel	1	-
Gas	-	4
Gas and Water	-	1
Petroleum	-	1
Propane Gas	-	1
Causes of Failure		
Age and Installation	7	5
Corrosion	1	-
Damage by this Department	1	-
Damage by other Utility	1	-
Cathodic Protection	-	5
Unknown	1	3

- Texas contacted their District Offices and provided a summary of responses about failures of pipelines in encasement as compared to noncased lines. The summary is presented in Table 1. There is only a slight difference in the total number of failures in cased versus uncased crossings and failure is not defined. However, cathodic protection appears to be a major cause of failure for cased pipeline crossings.
- West Virginia allows uncased pipeline crossings of highways for natural gas when certain criteria have been met. The State notes that the cost savings from using uncased crossings for natural gas pipelines is a benefit to both the utility companies and the rate paying public. The State also allows exceptions to its normal policy requiring encasement as follows:

a. Under municipal sections where not possible or practical.
b. Copper or steel pipe 1¼ in. or less nominal diameter.
c. Plastic pipe, meeting requirements of ASTM, D2513, Type 2306, 1¼ in. or less nominal diameter.
d. Cast or ductile iron gravity flow sewer pipe, mechanical, "push on", or flanged type joint meeting ANSI Specifications A21.6, A21.10, A21.11, A21.51, or Federal Specifications WW-P-421c, and AWWA Specifications C106, 110, 111, and 151, and of a thickness class capable of resisting the anticipated live and dead loads.
e. Rigid plastic gravity flow sewer pipe capable of resisting the anticipated live and dead loads.
f. Concrete sewer pipe.

- Tennessee and Alabama both allow uncased crossings while requiring additional protective measures including the use of higher factors of safety in the design, construction and testing than normally required for cased construction. Tennessee is not aware of any problems occurring with uncased crossings. Uncased crossings are generally less expensive to install and appear to be more trouble free.

Utility and industry group responses to requests for additional information provided some relevant data. Colonial Pipeline Company reported that they had installed 1,720 uncased road crossings in 10 states since 1972 ranging in diameter from 8 in. to 40 in. with no leaks, problems, or any other failures. They stated that maintenance costs have been negligible.

The American Water Works Association pipe and pipe installation manuals were virtually unchanged as they related to crossings from the previous study. The American Petroleum Institute's Recommended Practice 1102 (*4*) remains unchanged from the previous study.

RECENT DEVELOPMENTS

While the TRIS literature search revealed no new references on pipeline crossings of highways and railroads, responses from the American Gas Association, the U.S. DOT Office of Pipeline Safety (OPS), and the National Transportation Safety Board (NTSB) recommended some highly relevant sources. These included a report on a program being conducted by Cornell University for the Gas Research Institute (GRI) on "Practices for Pipeline Crossings at Railroads" (*5*). The "Pipeline Accident Report, Texas Eastern Gas Pipeline Company Ruptures and Fires at Beaumont, Kentucky on April 27, 1985 and Lancaster, Kentucky on February 21, 1986" (*6*) by the National Transportation Safety Board and transcripts of hearings (*7*) and related documents associated with the investigations of the accidents contained much valuable information. A program of pipeline inspection initiated as a result of these accidents also revealed valuable information.

The GRI research program has produced two reports (*5, 8*) that provide valuable information related to highway crossings. Although the reports focus on railroad crossings, much of the information is relevant to highways. Of particular interest was the information on design and construction methods for pipeline crossings, foreign practices, a review of catastrophic crossing failures, and corrosion control contained in the reports. Significant findings and recommendations of the report include the following:

- In the United Kingdom and the Federal Republic of Germany, gas pipeline regulations allow uncased pipeline crossings at railroads.
- The option to use thicker wall carrier pipes in lieu of casings at crossings is allowed in a 1984 revision of the British Institution of Gas Engineers recommendations and is also being considered in Canada for incorporation into industry specifications.
- The investigations of pipeline failures within casings at crossings by the NTSB indicate that casings can lead to potentially unsafe conditions. A review of NTSB accident reports shows that problem areas include atmospheric as well as galvanic corrosion control and longitudinal pipeline stresses due to carrier pipe flexure inside the casing.
- Casings have not successfully withstood the forces that occurred when transmission natural gas pipelines have failed within the casing.
- Poor bedding conditions can create additional ring bending stresses in a casing or in an uncased carrier pipe, and these stresses are not decreased with pressurization.
- Carrier settlement outside the casing and inadequate spacing of insulators inside the casing can combine to create a condition of contact between the casing and the carrier as well as substantial longitudinal bending stress in the carrier.
- The carrier pipe may be exposed to atmospheric corrosion as a result of its isolation from the casing and the circulation of air through vents attached to the casing.
- Casings can reduce or eliminate the effectiveness of cathodic protection.
- The problems associated with cathodic protection are compounded by difficulties in securing and interpreting meaningful measurements at cased crossings. The introduction of a casing creates a more complicated electrical system than would generally prevail for uncased pipe.

The NTSB Pipeline Accident Report on the Beaumont and Lancaster, Kentucky, natural gas pipeline explosions (*6*) contains information on both accidents, the investigations into the accidents, and recommendations related to the causes of each. The Beaumont accident occurred in carrier pipe within a casing under a state highway. The Lancaster explosion occurred in a section of pipeline near, but outside of, the casing near another state highway. Points of interest about both accidents from the Executive Summary of the *Accident Report* are noted in the following paragraphs:

- On April 27, 1985, natural gas under 990 psig ruptured the No. 10 pipeline of the Texas Eastern Gas Pipeline Company system. The rupture was in an area weakened by atmospheric corrosion that was located within the pipeline's casing under Kentucky State Highway 90 near Beaumont, Kentucky. The ensuing fire killed five persons in a house located north of the rupture, injured three persons as they fled from their houses located south of the rupture, and destroyed substantial amounts of property.
- On February 21, 1986, natural gas under 987 psig ruptured the No. 15 pipeline of the Texas Eastern Gas Pipeline system. The rupture was in an area weakened by galvanic corrosion and was located south of Kentucky State Highway 52 near Lancaster, Kentucky. The force of the escaping gas and the ensuing fire injured three persons as they fled from their houses, resulted in the evacuation of 77 other persons, and destroyed substantial amounts of property.
- The National Transportation Safety Board determined that the probable cause of the pipeline accident near Beaumont, Kentucky, was the unsuspected and undetected atmospheric corrosion of Texas Eastern Gas Pipeline Company's 30-in.-diameter pipeline in a casing under State Highway 90. Contributing to the accident was the failure of the pipeline industry and of the U.S. DOT Office of Pipeline Safety to recognize the need for, and to require the use of, in-line corrosion detection techniques for identifying and monitoring the existence and severity of corrosion in casings and other areas shielded from corrosion protection.
- The probable cause of the pipeline accident near Lancaster, Kentucky, was the failure of the Texas Eastern Gas Pipeline Company to fully investigate the extent and severity of previously detected and inspected corrosion-caused damage and to replace the damaged segment of pipeline before its failure. Contributing to the accident was the lack of gas company guidelines for its personnel for further inspection and the shut down or reduction in line pressure when corrosion damage on its pipelines is detected.
- As a result of its investigations of these accidents, the Safety Board issued recommendations to: upgrade the qualifications

and training of gas company employees; require complete inspections for corrosion-caused damage of buried pipelines that have been excavated; require periodic affirmation through inspections and tests of the maximum allowable operating pressure of pipelines; require periodic inspections for corrosion damage of pipelines installed in vented casings; require changes in pipelines to facilitate use of in-line inspection equipment; and provide additional and more specific guidance on corrosion control practices and corrosion monitoring procedures.

Investigations into these pipeline failures also included a public hearing on the Beaumont accident in October 1985 (*7*). This hearing explored the reasons for using casings for pipeline crossings and the adverse effects the use of casings may have. While pipeline industry organizations declined to participate, testimony from gas company, state, federal, and railway industry representatives was given. Some relevant points of this testimony included in the report are:

- The gas company representatives stated that many sections of pipe had been removed from casings when pipe was being relocated because of road construction and other activities. Inspection of the removed pipe sections showed that the pipe was in good condition with only minor areas of corrosion. Furthermore, minor leakage of gas has been the only result experienced due to corrosion of pipe installed within casings; no major ruptures had ever been experienced before these accidents by the gas company.
- The representative of the OPS stated that he knew of no statistics on pipeline failures directly applicable for assessing the effect, if any, casings may have on the overall safety of buried pipelines. However, from the records of OPS there is no indication that the failure of pipelines that are encased has resulted in a significant threat to public safety. The OPS does not require the casing of pipelines for crossing road or for any other reason; however, if a casing is used, the OPS regulations incorporate specific actions which must be taken (49 CFR 192.323 and 192.467 (c)).
- Representatives of the Federal Highway Administration (FHWA), DOT, and the American Association of State Highway and Transportation Officials (AASHTO) commented that before 1959 the Federal Government and most of the States favored the use of casings for pipeline crossings under highways. Since 1959 there has been no policy specifically requiring the use of casing. Instead, the policy has been to leave the decision concerning the use of casings up to the individual State Highway Departments.
- The representative of the Kentucky State Highway Department concurred with the FHWA and AASHTO representatives. He stated that Kentucky had a policy in the 1950's which generally required the casing of pipeline crossings under highways. However, this policy was changed to allow the uncased crossing of pipelines where heavier pipe wall and improved insulating coatings were used. The change in policy came about because pipeline companies have been able to demonstrate that the heavier wall pipelines could safely withstand the forces imposed by the highway and vehicular traffic and in so doing the pipeline could be better protected against corrosion within the highway right-of-way.
- The representative of the American Railway Engineering Association (AREA) stated that it endorses the casing of pipelines crossing under railroads to protect against damaging the railroad should the pipe leak or rupture. While individual railroads are not mandated to follow this policy, in practice, most railroads do require the use of casings for pipelines crossing their rights-of-way. The representative further stated that by following good construction and inspection practices, operators of pipelines should experience no problems as a result of these casings.

A detailed review of the transcripts of the October 1985 hearings on the accidents conducted by the NTSB (*7*) was also made. Of interest was:

- The testimony concerning the detection of corrosion from currently used testing methods. Testimony described the difficulty in interpreting readings of pipe to soil potential to determine if pipes were shorted, were shielded, or active corrosion was present within casings.
- The AREA representative cited an example of a pipeline failure under a railroad and roadway in Mississippi where the roadway collapsed, but the railroad did not because the pipeline under the railroad was cased. He also stated that not using casings would, in effect, be an experiment.
- The U.S. DOT OPS representative discussed statistics related to gas transmission incidents recorded by his organization. Of 7,192 incidents of gas transmission lines (for all lines, not only highway crossings) between 1970 and 1982, 54 were attributed to corrosion in a road right-of-way. Although records do not indicate if pipelines were or were not encased, he felt the majority were probably encased. An incident is a leak, requiring reporting to the OPS, which caused death or serious injury or property damage greater than $50,000, but many of the incidents were reported under the older criteria of $5,000 in property damage. He stated that while the OPS is neutral on whether casings should be required or not, engineering judgment should be used and casing may be desirable in some locations.
- The Kentucky Department of Highways representative stated that the Department now allows utility companies to decide if casings are required or not. However, most District Engineers insist on casings.

As a result of the accidents in Kentucky involving the Texas Eastern Gas Pipeline Company, a program to check all pipelines of the company in Kentucky was initiated. This survey used a lina-log device to check for corrosion in pipelines. This device is placed in a pipe section and travels in the gas. By taking electromagnetic readings, it can detect corrosion in the line. The corrosion survey of three pipelines in Kentucky revealed that for 364 cased pipelines crossings, 26 were shorted and 20 were corroded. For the corroded crossings, 5 were replaced, 7 were filled or scheduled to be filled with a dielectric filler, and all were scheduled for more frequent monitoring.

CHAPTER THREE

INTERPRETATION, APPRAISAL, AND APPLICATION

Despite evidence suggesting that encasing pipelines with steel casing may not be the most appropriate protection for all pipelines crossing highways, many agencies continue to require such protection. The wording of AASHTO's *A Guide for Accommodating Utilities Within Highway Right-of-Way* (*9*) calls for encasement or an alternate means of providing the same degree of protection afforded by encasement. Many state highway agencies, in adopting the wording of the *AASHTO Guide,* have thus made encasement the first choice for most pipeline crossing situations. When a highway official is faced with the decision to approve or disapprove a utility's proposed pipe crossing, encasement would appear to be the best or most conservative means of providing protection.

The *AASHTO Guide* was based on experience and practices of almost 30 years ago. Since then, improvement have been made in the methods of providing protection for pipelines crossing highways. More experience has been gained in the problems of encasement and alternatives to it. A need exists, therefore, to provide information related to pipeline protection for highway crossings to highway officials. The intent of this project is to develop guidelines for pipeline protection through highway roadbeds that will provide such needed information. The guidelines for the protection of pipelines through highway roadbeds are contained in Appendix A.

The guidelines have been developed based on research for this project and that of NCHRP Project 20-7, Task 22. The guidelines give highway officials factors to consider in approving a proposed pipeline crossing of a highway and descriptions of currently available methods of providing pipeline protection. The guidelines avoid the requirement of encasement as the first choice for a pipeline crossing, but consider encasement as one of several different alternatives.

The guidelines have been kept general in nature and do not go into details of design or construction. Because the design and construction of a pipeline crossing is usually the responsibility of the utility, such information would not normally be required by highway officials. These guidelines in Appendix A have been kept as concise as possible to give the highway official a brief "tool" to assist in the approval of proposed pipeline crossings.

These guidelines are not intended as the definitive work on pipeline protection for highway roadbeds because of their general nature and the fact that the methods of protection are based on current practice. Protection methods will no doubt change and improve. These guidelines should therefore be used with an understanding of when they were developed and their limited intent.

CHAPTER FOUR

CONCLUSIONS AND SUGGESTED RESEARCH

The guidelines proposed in Appendix A are intended as a useful aid for highway officials in approving or disapproving proposed utility crossings of highways. They are based on available information and practices and provide highway officials a rational approach to decision-making. The guidelines are general enough so that they can and should be modified and adapted for local use. They can also be updated or modified as protection methods change. Over time, research should be conducted to ensure the validity of these guidelines and to modify them, as necessary, based on evolving practice.

APPENDIX A

GUIDELINES FOR THE PROTECTION OF PIPELINES THROUGH HIGHWAY ROADBEDS

INTRODUCTION

Utility and transportation networks have long shared common rights-of-way and will continue to do so as both networks continue to grow. As these networks intersect at common rights-of-way, problems often arise when construction, maintenance, and operations of one network affect the operations of the other network. Because of the importance of both highway and pipeline networks to the public, it has been recognized that they should be protected from each other. Pipeline crossings should minimize the utilities' interference with traffic and highway operations. Highway maintenance, repair and expansion operations should also be taken into account as they affect utility operations.

Each highway agency has the responsibility to maintain the right-of-way of highways under its jurisdiction to preserve the operational safety, integrity, and function of the highway facility. Highway agencies derive their authority to designate and to control the use made of right-of-way acquired for public highway purposes from state laws or regulations. Because the safety, integrity, and function of a highway can be affected by the manner in which utilities cross the highway, states have regulated the crossing of pipelines through highway roadbeds. States must comply with the requirements of the AASHTO *Policy on the Accommodation of Utilities on Freeway Rights-of-Way* (*10*) for pipelines crossing Interstate and other Federal-Aid freeways. This policy requires that crossings maintain the safety and integrity of the highway. Many states also follow AASHTO's *A Guide for Accommodating Utilities Within Highway Right-of-Way* (*9*, hereinafter referred to as the *AASHTO Guide*) for highways under their jurisdiction. This guide provides recommendations on the crossing of highways by various utilities and was first approved in 1969. Much of the wording of the guide is from an American Society of Civil Engineers (ASCE) study and related research done in the late 1950's and early 1960's (*11*).

Utilities may also be granted permission to install their lines and facilities on the right-of-way of public roads and streets. Such authorization or permission also depends on state laws and regulations. Utilities additionally depend on franchises, local laws, and ordinances to install their lines. Natural and other gas and hazardous liquid pipelines must also comply with Title 49, Transportation, *Code of Federal Regulations* (*3*, hereinafter referred to as CFR), which require additional precautions for pipelines crossing highways.

While utilities are usually responsible for the design of pipelines crossing highways, highway agencies are responsible for review and approval of the utilities' proposed crossing with respect to the location of the utility facilities to be installed and the manner of installation. Conflicts can arise over the design of pipeline crossings and the degree of additional protection required.

It should be noted that relatively few incidents of pipeline failure have occurred in the past three decades since the Interstate System was started and utility policies began to be established for highway rights-of-way. Available interstate pipeline system leak and incident data do not identify the cause or frequency of leaks or incidents at crossing locations, but it is believed to be a fairly minor problem. There is no national database of interstate pipeline incidents from which to draw conclusions about water or sewer line crossings of highways, but this is also believed to be a minor problem. Isolated reports of incidents of water main breaks or dig-ups can be found, but there is not a comprehensive database of water line or sewer line failures. Four catastrophic failures of encased petroleum and natural gas pipelines, however, have occurred at highway crossings which resulted in the loss of life and property.

Summary of Guidelines

In order to alleviate potential conflicts regarding the protection of pipelines at crossings, it is the intent of these guidelines to assist highway agencies in reviewing and approving such crossings. These guidelines outline the factors that should be considered in approving proposed pipeline crossings of highways and discuss appropriate protection methods for various situations. Each crossing should be evaluated as the unique situation that it is, and these guidelines will assist highway agencies in that evaluation.

Factors that should be considered for each pipeline crossing situation will vary. However, the following factors should be taken into account in approving protection measures:

- Pipeline size.
- Operating pressures.
- Nature of the transported material.
- Road classification and the probable causes and consequences of leakage for the road.
- Carrier pipe design.
- Required cover.
- Vertical and horizontal location of the pipe.
- Allowable construction methods.
- Corrosion protection.
- Future highway widening and construction.

Also, an understanding of the available protection methods is desirable in providing protection for pipeline crossings. Methods in use include: protective slabs, cradles or walls, encasement pipes or sleeves, concrete encasement, thickened wall pipe, tunnels or galleries, cathodic protection, and leak-proof joints.

For each of these protection measures, there will be advantages and disadvantages. Costs for construction and maintenance of different equal alternatives will often govern the selection of the most appropriate alternative.

Application

The guidelines apply to all public and private utilities in pipelines, including but not limited to water, gas, oil, petroleum products, steam, sewage, drainage, irrigation, and similar facilities that are to be located, adjusted, or relocated to cross rights-of-way of highways under the jurisdiction of highway agencies.

Scope

These guidelines are provided for use by highway agencies in regulating the design and methods for installing, adjusting, accommodating, and maintaining pipeline utilities crossing highway rights-of-way. They do not alter current regulations or authority for installing utilities, nor do they determine financial responsibility for replacing or adjusting utilities. They are merely guidelines intended to assist highway authorities in preserving the safe operation and integrity of highway systems.

Where laws or orders from public authorities, including state highway authorities, industry or governmental codes, prescribe a higher degree of protection than recommended by these guidelines, the higher degree of protection should be provided. These guidelines supplement, but do not alter, the provisions of the AASHTO *Policy on the Accommodation of Utilities Within Freeway Rights-of-Way.*

DEFINITION OF TERMS

Following are definitions for terms used in this guide:

Cap—rigid structural element surmounting a pipe, conduit, casing, or gallery.
Carrier—pipe directly enclosing a transmitted fluid (liquid or gas).
Casing—a larger pipe enclosing a carrier.
Clear zone—that roadside border area, starting at the edge of the traveled way, available for use by errant vehicles.
Coating—material applied to or wrapped around a pipe.
Cover—depth of fill over top of pipe, conduit, casing, or gallery to grade of roadway or ditch.
Cradle—rigid structural element below and supporting a pipe.
Encasement—structural element surrounding a pipe.
Flexible pipe—a plastic, fiberglass, or metallic pipe having a large ratio of diameter to wall thickness which is designed for diametric deflection greater than 3 percent.
Gallery—an underpass for two or more utility lines.
Grout—a cement mortar or a slurry of fine sand.
Highway, street, or road—a general term denoting a public way for purposes of vehicular travel, including the entire area within the right-of-way.
Jacket—encasement by concrete poured around a pipe.
Normal—crossing at a right angle.
Pavement structure—the combination of subbase, base course, and surface course placed on a subgrade to support the traffic load and distribute it to the subgrade.
Pipe—a tubular product made as a production item for sale as such. Cylinders formed from plate in the course of the fabrication of auxiliary equipment are not pipe as defined here.
Pressure—relative internal pressure in psig (pounds per square inch gauge).
Right-of-Way—a general term denoting land, property, or interest therein, usually in a strip, acquired for or devoted to transportation purposes.
Rigid pipe—pipe designed for diametric deflection of less than 1 percent.
Roadway—the portion of a highway, including shoulders, for vehicular use. A divided highway has two or more roadways.
Slab, floating—slab between, but not contacting, pipe or pavement.
Sleeve—encasement structure of steel or concrete.
Traveled way—the portion of the roadway for the movement of vehicles, exclusive of shoulders and auxiliary lanes.
Trenched—installed in a narrow open excavation.
Untrenched—installed without breaking ground or pavement surface, such as by jacking or boring.
Vent—appurtenance to discharge gaseous contaminates from casing.
Walled—partially encased by concrete poured alongside the pipe.

CONSIDERATIONS FOR PIPELINES CROSSING HIGHWAYS

The following general considerations are suggested for the location, selection of protection and design of pipeline installations crossing highway rights-of-way:

Location

Pipelines should be located to minimize the need for later adjustment to accommodate future highway improvements and to permit servicing such lines with minimum interference to highway traffic.

To the extent feasible and practicable, pipeline crossings of the highway should cross on a line generally normal to the highway alignment. Such alignment should present the least disturbance to the roadbed by being the shortest crossing distance.

The location of above-ground appurtenances for pipelines within the highway right-of-way limits should conform with the clear zone policies applicable for the system, type of highway, and specific conditions for the particular highway section involved. The depth of cover for pipelines under ditches should be adequate to protect the pipeline from ditch maintenance and repair activities.

In all cases, full consideration should be given to the measures, reflecting sound engineering principles and economic factors, necessary to preserve and protect the safety of highway traffic, its maintenance efficiency, and the integrity and visual quality of the highway.

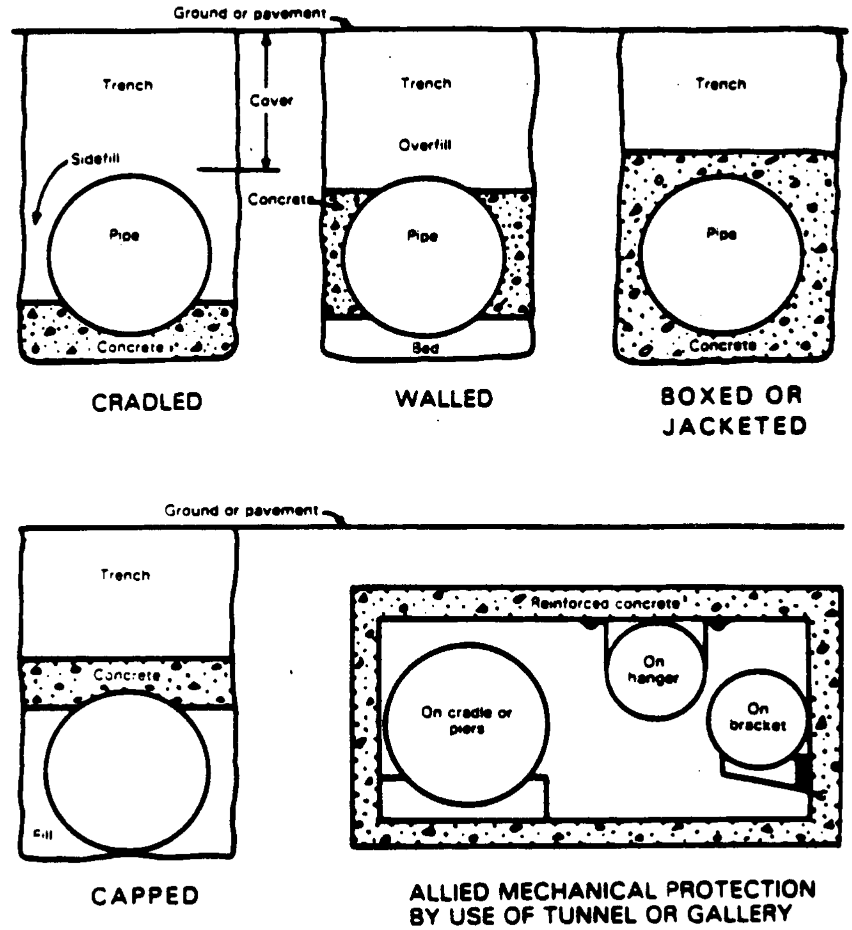


Figure A-1. Trenched protective measures. (From Ref. 9, by permission)

Construction Method to be Used

Whether the pipeline crossing is built using trenched or untrenched construction techniques helps determine the method of protection provided. Trenched construction is installing the pipe in a narrow, open excavation while untrenched is jacking or boring the pipe without breaking the ground or pavement. Methods of providing protective measures for trenched construction are shown in Figure A-1 and for untrenched in Figure A-2. Trenched construction provides more options for protective measures; however, it is often impractical to use. Traffic is disrupted during construction. The pavement is cut and the subgrade is disturbed, which often leads to later settlement and pavement damage. As a result, many highway agencies prohibit

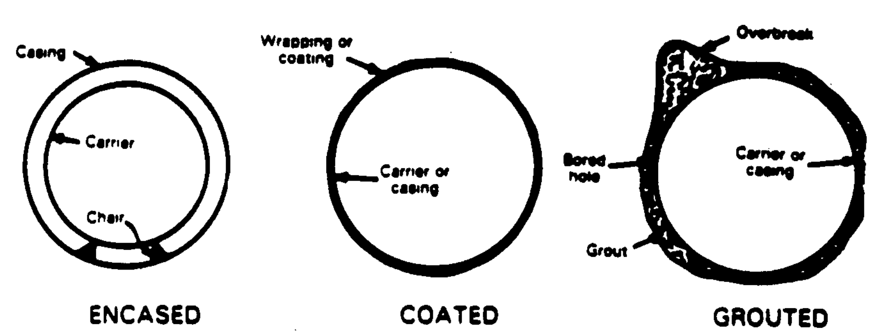


Figure A-2. Untrenched protective measures. (From Ref. 9, by permission)

Table A-1. Trenchless construction methods. (From Ref. 5)

Method	Lining Type and Range of Internal Diameter, in. (mm)	Length of Drive, ft (mm)	Suitable Ground Conditions	Steering and Accuracy, in. (mm)	Surface Access (Pit Length × Width), ft (m)[b]
Pipe jacking with remotely controlled tunneling and excavation shields	Jacked pipe 12 to 36 (300 to 900)	Max to date 400 (120)	All except rock and large boulders. Excavation shields are designed to limit ground movements.	Steerable; typical accuracy ± 1 (25).	20 × 7 (6 × 2) launch pit; 10 × 7 (3 × 2) reception pit.
Pipe jacking with auger borer	Jacked pipe 6 to 36 (150 to 900)	Up to 330 (100), often less	All except hard rock and boulders. Risk of ground movement in soft clay and loose sand with obstructions.	At best accuracy about ± 2 (50), but decrease with distance.	10 × 7 (3 × 2) launch pits; 7 × 7 (2 × 2) reception pit.
Percussive moling	Pulled plastic or steel pipe 2 to 8 (50 to 200)	Max 230 (70), but typically 100 (30)	Not suitable for very soft ground or rock. Can break up small boulders. Minimum heave at depths greater than 10 × pipe diameter.	No control once launched. Best accuracy ± 4 (100) in 100 ft (30 m).	7 × 5 (2 × 1.5) launch pit; 5 × 5 (1.5 × 1.5) reception pit.
Horizontal drilling	Steel pipe 2 to 36 (50 to 200)	Max 4200 (1300)	Can be used in most soils.	Steerable by use of special drilling tools. Turning radius controlled by pipe diameter.	Drilling normally from surface-mounted rig.
Pipe ramming	Driven steel pipe 2 to 36 (50 to 200)	Max 200 (60)	All except rock and boulders. May be able to chisel soft rock. May cause heave in clay and dense sand.	Little control once drive started. Best accuracy ± 4 (100).	16 × 5 (5 × 1.5) launch pit; 5 × 5 (1.5 × 1.5) reception pit.
On-line replacement	Plastic pipe 4 to 16 (100 to 400)	Max to date about 300 (100).	Suitable for most soils.	Uses existing pipe as pilot tunnel.	7 × 5 (2 × 1.5) launch pit; 5 × 5 (1.5 × 1.5) reception pit.

[a]Adapted from report prepared by Binnie and Partners, 1985.

[b]Dimensions for launching and receiving pits are generally minimum required dimensions. Larger dimensions are commonly used to expedite construction processes.

the use of trenched construction except in specific situations.

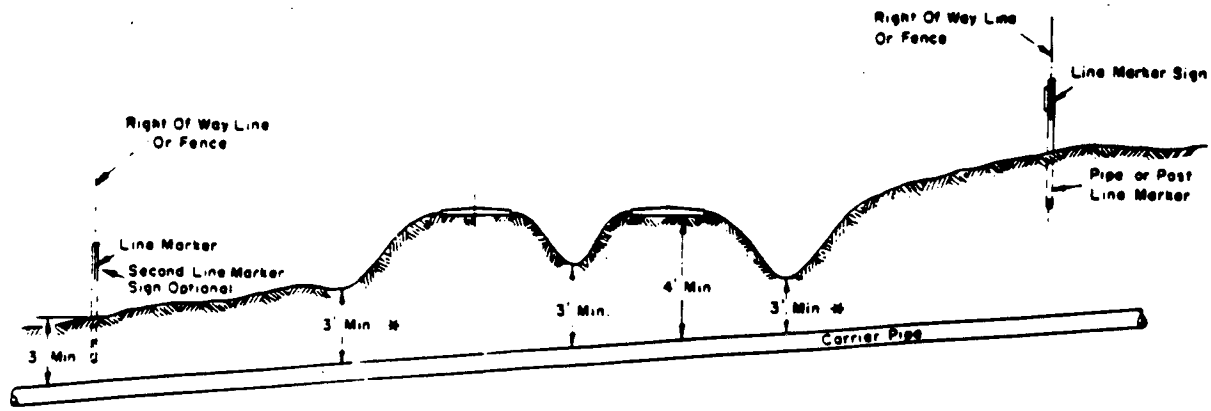
Untrenched construction has the advantage of not disrupting traffic or breaking the pavement surface. Table A-1 presents various untrenched construction methods and associated characteristics. Jacking or ramming techniques can cause damage to the pipe or the pipe's protective coating. Casing pipe, jacking pipe, thickened wall pipe, grouting, or precast concrete coverings may be used to prevent or mitigate such damage. Drilling or boring may also cause damage to protective coatings, and precast concrete coverings can be used to protect the carrier pipe. Suitable ground conditions for each type of untrenched construction are given in Table A-1. Because of the potential for damage to the carrier pipe during untrenched construction, additional protective measures for crossings may be warranted even if other warrants for protection do not exist.

Cover

The depth of cover for a pipeline crossing is most critical at the low points of the highway section. Because these are usually the bottoms of longitudinal ditches, such points are very likely to be subject to frequent maintenance operations including ditch cleaning, widening, or deepening. Scour may also increase the depth of unpaved ditches. Damage from maintenance activities is one of the most frequent causes of pipeline failure. The depth of cover is therefore a determining factor in whether additional protection is required for a pipeline. The greater the depth of cover, the less critical the need for additional protection. Figure A-3 shows a typical highway cross section and recommended minimum cover depths for petroleum pipelines. These cover depths are recommended by the American Petroleum Institute and comply with the Federal regulations for hazardous liquids.

Suggested controls for cover of pipelines are also contained in the *AASHTO Guide.* These controls include the recommendation that depth of cover be established by each highway agency based on engineering and safety factors, the product carried, and the maximum working or test pressures for the pipelines. The *AASHTO Guide* also recommends that pipelines be rerouted or protected if minimum cover cannot be obtained because of other utilities, water table, local ordinances, or similar reasons.

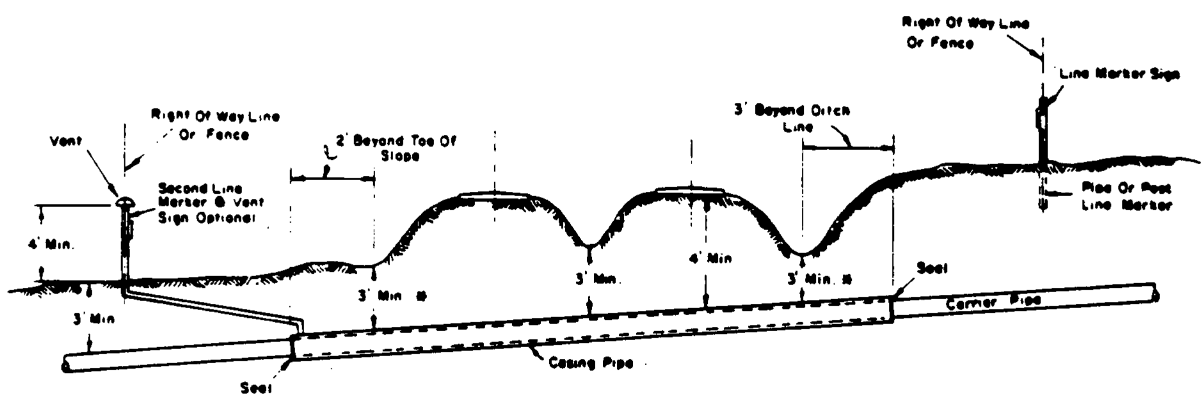
Gas pipelines must comply with the safety standards and specifications of both the CFR and state regulatory bodies. Required CFR minimum depths of cover for gas pipelines are 30 in. in Class I locations in normal soil; 18 in. in consolidated rock; 36 in. in Class II, Class III, Class IV, and ditch locations in normal soil; and 24 in. in consolidated rock. Classes are determined based on the proximity of a pipe to buildings or structures, with Class I locations being the most remote from populated areas or buildings. Federal codes for minimum cover depths for all liquids are the same as the API recommended depths of cover shown in Figure A-3.



HIGHWAY CROSSING

*For pipelines transporting LPG this dimension shall be 4' min.

EXAMPLE OF
UNCASED CROSSING INSTALLATIONS



HIGHWAY CROSSING

*For pipelines transporting LPG this dimension shall be 4' min.

EXAMPLE OF
CASED CROSSING INSTALLATIONS

Figure A-3. Critical dimensions—depth of cover. (Dimensions for petroleum pipelines from API Recommended Practice 1102)

Assessment of Consequences of Pipeline Failure

An assessment of the potential consequences of the failure of a pipeline at a particular crossing will aid in approving appropriate methods of protection for that pipeline. The assessment should include the following steps: (1) classify the materials being transported, (2) identify causes and consequences of failure, (3) evaluate if additional protection is required for the crossing, and (4) if additional protection is required, identify appropriate protection methods.

Step 1—Classify Material Being Transported

The material should be classified as either hazardous or nonhazardous. Hazardous materials for pipeline crossings are flammable, corrosive, or toxic. Such materials, if spilled, cause loss of life or serious injury, property damage, or environmental contamination. It is critical to know whether or not a material is hazardous in assessing the consequences of a pipeline failure. Special Federal or State regulations may apply to the transport of hazardous materials that must be complied with. Federal regulations covering pipelines are in Title 49 of the *Code of Federal Regulations,* Part 192—Transportation of Natural and Other Gas by Pipelines: Minimum Federal Safety Standards, and Part 195—Transportation of Hazardous Liquids by Pipeline. Part 192 requires that different design factors be used for various crossing situations for the steel pipe design formula. The design factor in the design formula decreases for a pipeline crossing a highway, which results in the requirement for lower pressure or greater wall thickness than pipe not at a crossing. Part 195 requires that pipes at highways be installed to adequately withstand dynamic forces expected by anticipated traffic loads. Accounting for traffic loads generally increases the pipe pressure, which results in a need for thicker pipe.

The pressure of materials being transported is also important. Pressures of 1000 psig or more may be found in natural gas or petroleum transmission pipelines. Transmission pipelines carry large volumes of materials from supply or source points to localized distribution systems. Distribution pipelines are generally lower pressure and smaller pipes that are used to provide products to consumers. Natural gas pressure in distribution piping may be as low as 0.25 psig. Lower pressures can also be found in water, sanitary sewer, or other pipelines. In addition to transmission or distribution pipelines, collector systems are also used. Collector systems for natural gas or petroleum products draw materials into collection or storage points for further refining, storage, and transmission. Collector pipe system pressure and sizes vary, depending on the volume of materials being transported.

Step 2—Identify Causes and Consequences of Pipeline Failure at Crossing Site

Pipelines may fail at highway crossings, although the frequency of such failures is low. From records of catastrophic failures and available information from pipeline operators and highway agencies, pipeline crossing failures are most likely caused by:

- Damage of pipelines from construction or maintenance operations.
- Corrosion leading to leakage or rupture.
- Differential settlement of crossing pipe relative to line pipe resulting in increased pipe stresses or failure of corrosion protection systems.
- Pressure surges that overstress pipes.

Because of the frequency of roadside and highway maintenance and construction operations, the likelihood of damage to pipelines from such operations is relatively high and is the most common cause of pipeline failure. Operations such as ditch cleaning and reshaping, installation of additional utilities or drainage structures or road widening or realignment occur near pipelines crossing highways. Pipelines can be struck or dug up during excavations or be overstressed from heavy construction vehicle loads.

Corrosion damage occurs in metal pipes when moisture and oxygen come into contact with metallic surfaces. The electrical properties of soil also affect corrosion. Metal pipes are usually protected from corrosion by coatings and cathodic protection systems. The CFR requires both coatings and cathodic protection for natural gas and hazardous liquid pipelines. Coatings, however, may be damaged during coating application, pipe installation, maintenance, or repair. Cathodic protection systems may be defeated by short circuits, shielding, or loss of current. Corrosion can lead to a loss of pipe thickness and thus reduced stress capacity.

Differential settlement occurs when a pipeline in a highway embankment settles at a rate different from that of the pipeline in adjacent areas. Differential settlement can induce stresses in pipes and cause pipe bending. Pipe bending can cause short circuits in cathodic protection systems if metal sleeves are used for pipeline protection (see Fig. A-4).

Pressure surges in pipelines can overstress pipelines and cause failures. While pressure surges are unlikely to overstress pipe

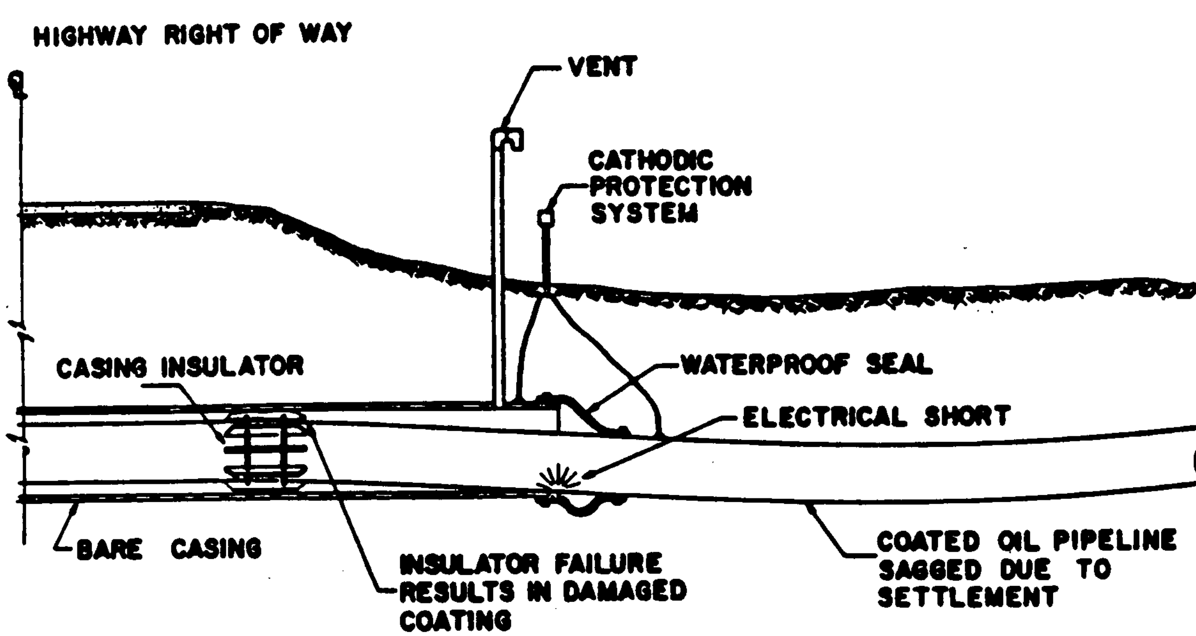


Figure A-4. Differential settlement of cased crossing and resulting short circuit. (From Ref. 12) in good condition, pipe that has been previously damaged, corroded, or stressed from settlement may fail because of a pressure surge.

When any of the foregoing causes of failure are possible at a particular crossing site, the outcome of a failure occurring should be evaluated. There are many outcomes or consequences that may result from a pipeline failure at a highway crossing, but the most probable consequences are: the loss of pavement subgrade of highway embankment because of release of materials being transported, contamination of the highway and adjacent areas because of spill or release of materials, and fire or explosion if flammable materials are released from the pipeline.

These consequences will vary in severity depending on the type, volume, and pressure of the material in the pipeline and the location of the pipeline. For example, slow water leaks may lead to pavement damage requiring future repairs to the highway, while a water main break may wash out the road and damage property necessitating emergency repairs. A break in a petroleum products pipeline may: destroy the subgrade and pavement of the road making it impassable; contaminate adjacent ditches and surface water; and ignite, endangering life and property. Loss of the utility service may also be a serious consequence of a pipeline failure.

Step 3—Evaluate if Additional Protection is Required

The next step in assessing the consequences of pipeline failure at a crossing site is to evaluate if additional protection is required. This evaluation should be based on the type of materials being transported and the potential causes and consequences of failure at a site. The CFR requires a variation in the design formula for steel pipe for natural and other gases at a highway crossing and requires traffic loadings be accounted for in the design of hazardous liquid pipeline crossings. These additional requirements generally result in the need for thicker pipe, which may be sufficient for a particular crossing site, and no other protection may be necessary. Similarly, no additional protection may be necessary for nonhazardous liquids at a particular low volume road crossing site, and normal line may be allowed.

Step 4—If Additional Protection is Required for a Crossing, Identify Appropriate Protection Methods

When additional protection is warranted for a pipeline crossing of a highway, it is usually the responsibility of the utility to select and design the protection method. Highway agencies are then responsible for the review and approval of the proposed crossing. Highway officials involved in the review process should approve appropriate protection methods for a particular situation. Protection methods include: protective slabs, cradles or walls, encasement pipes, concrete encasement (includes grouting, boxing, or jacketing), thickened wall pipe, tunnels or galleries, cathodic protection, and leak-proof joints.

Suggested protection measures for the potential causes and consequences of a pipeline crossing failure are graphically presented in Figure A-5.

In order to use Figure A-5, the causes of pipeline crossing failure for a site should be identified in the first column of the matrix labeled "Causes". Probable consequences of failure for each selected cause should then be selected from the second or "Consequence" column. For each cause and consequence selected as valid for a particular crossing, appropriate "Protection" methods are marked in the third section of the matrix. Any crossing situation may result in several combinations of causes, consequences, and appropriate protection methods. Some protection measures will be appropriate for multiple combinations of causes and consequences and will thus be more appropriate for a site. However, the allowed method of construction, location, and cover may preclude the use of certain protection methods.

For example, a natural gas pipeline crossing is proposed for a highway in a cut section. Settlement is not anticipated as a problem. Because of the utility's equipment and operating procedures, pressure surges are also not considered a potential cause of failure. Accordingly, "Damage" and "Corrosion" are selected in the causes column as shown in Figure A-6. If pipeline failure occurred, a fire, explosion, or destruction of the roadbed could occur. These consequences are selected. Because the highway cannot be closed during construction of the pipeline, untrenched construction methods must be used. With this in mind, appropriate untrenched protection methods are found in the "Protection" block. Appropriate protection methods for the described situation would include encasement pipe, concrete encasement, thickened wall pipe or cathodic protection. In this situation, cathodic protection would be required because of the requirements of the CFR. Encasement pipe, thickened wall pipe, concrete encasement, or a combination of these methods would be appropriate to provide protection in addition to the cathodic protection required by the CFR. Because damage from construction or maintenance activities is the most common cause of pipeline crossing failures, encasement pipe or concrete encasement would be preferable over thickened wall pipe alone. If other factors, such as soil conditions, are not a problem for this proposed crossing, a utility's request to use encasement pipe, thickened wall pipe, concrete encasement, or a combination of methods should be approved.

Corrosion

Corrosion can be a serious problem for buried metallic pipes. Corrosion can eventually lead to pipe failure by reducing the wall thickness of pipes and, thus, reducing their capacity to handle stresses. Because pipes are buried, detecting corrosion damage is difficult. Failure of corrosion protection measures can be minimized, however, by ensuring their proper installation during construction. The following should be considered in relation to corrosion of metal pipelines crossing highways:

- The CFR requires that both natural gas and hazardous liquid steel pipelines be covered with protective coatings and cathodically protected.
- Coatings for steel pipelines damaged during manufacture or installation should be repaired prior to backfilling.
- Because coatings damaged during jacking or boring operations cannot be repaired, soil conditions must preclude coating damage. If this is not the case, additional carrier pipe protection will be required. Uncoated steel casing pipe, special coatings of tough durable materials or concrete-coated carrier pipe can be used in difficult soil conditions to avoid damage to protective carrier pipe coatings.

CAUSES	CONSEQUENCES			PROTECTION							
	Embankment/ Subgrade Loss	Spill	Fire or Explosion	Floating Slab or Cap	Cradle or Wall	Encasement Pipes	Concrete Encasement	Thickened Wall Pipe	Tunnel or Gallery	Cathodic Protection	Leak-Proof Joints
Damage from Construction or Maintenance Activities	●			●		●	●		●		
		●		●		●	●		●		
			●	●		●	●		●		
Corrosion (metal pipes only)	●						●	●		●	
		●					●	●		●	
			●				●	●		●	
Settlement	●				●	●	●	●			●
		●			●		●	●			●
			●		●		●	●			●
Pressure Surge	●					●		●			●
		●						●			●
			●					●			●

Figure A-5. Identify causes, consequences, and suitable protective measures for pipelines crossing highways.

• If steel casing pipe is used, casing and carrier pipe must be cathodically protected as a unit or the pipes must be electrically isolated. Electrical isolation is provided, as shown in Figure A-7, by insulators. Electrical isolation can be defeated if: insulators are damaged or not spaced properly during insertion of the carrier in the casing; differential settlement causes short circuits; or water acting as an electrolytic solution is present in the carrier/casing spacing.

Design

The utility is responsible for the design of the pipeline crossing the highway rights-of-way. The highway agency is responsible for review and approval of the utility's crossing proposal. The highway agency review should include the measures to be taken to preserve the safe and free flow of traffic, structural integrity of the roadway, ease of highway maintenance, appearance of the highway, and the integrity of the utility facility.

Utility installations under the right-of-way of state highways should, as a minimum, meet the following design requirements:

1. Water lines should conform with the current applicable specifications of the American Water Works Association.
2. Pressure pipelines should conform with the currently applicable sections of the Standard Code of Pressure Piping of the American National Standards Institute; Title 49 CFR, Parts 192, 193, and 195; and applicable industry codes.

CAUSES	CONSEQUENCES: Embankment/ Subgrade Loss	CONSEQUENCES: Spill	CONSEQUENCES: Fire or Explosion	PROTECTION: Floating Slab or Cap	PROTECTION: Cradle or Wall	PROTECTION: Encasement Pipes	PROTECTION: Concrete Encasement	PROTECTION: Thickened Wall Pipe	PROTECTION: Tunnel or Gallery	PROTECTION: Cathodic Protection	PROTECTION: Leak-Proof Joints
Damage from Construction or Maintenance Activities	●			●		●	●		●		
		●		●		●	●		●		
			●	●		●	●		●		
Corrosion (metal pipes only)	●						●	●		●	
		●					●	●		●	
			●				●	●		●	
Settlement	●				●	●	●	●			●
		●			●		●	●			●
			●		●		●	●			●
Pressure Surge	●					●		●			●
		●						●			●
			●					●			●

Figure A-6. Example to identify causes, consequences, and suitable protective measures for a highway crossing.

3. Liquid petroleum pipelines should conform with the currently applicable recommended practice of the American Petroleum Institute for pipeline crossings under railroads and highways.
4. Any pipeline carrying hazardous materials shall conform to the rules and regulations of the U.S. Department of Transportation governing the transportation of such materials.

Specific provisions of these requirements are given in Table A-2.

All utility installations under highway rights-of-way should be of durable materials designed for long service life expectancy and relatively free from routine servicing and maintenance. Utility installations should have at least the service life of the highway they are crossing, which is usually in the 20-year to 30-year range.

On new installations or adjustments to existing utility lines, provisions should be made for known or planned expansion of the utility. Such provisions should be planned so as to minimize hazards and interference with highway traffic when additional underground lines are installed at some future date.

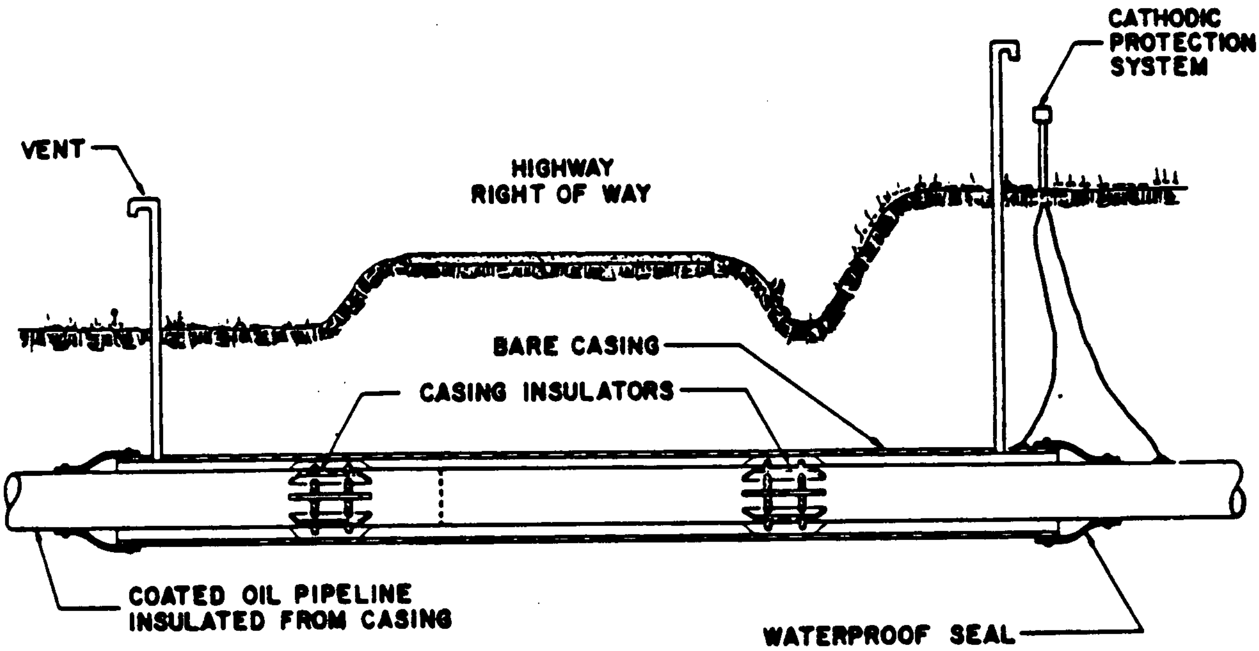


Figure A-7. Pipeline in casing under highway right-of-way. (From Ref. 1)

Table A-2. Applicable standards.

A. Water Lines
   1. Section of AWWA C600-82, Standard for Installation of Gray Ductile Cast Water Mains and Appurtenances - Summary
   2. Section 7-2 of AWWA M23, PVC Pipe Design and Installation Manual - Summary
   3. Chapter 6, 10, and 11 of AWWA M11, Steel Pipe - A Guide for Design and Installation
   4. Page 70-73 from AWWA M9. Concrete Pressure Pipe Manual - Summary

B. Gas Pipelines
   1. Title 49, Code of Federal Regulation, Part 192 "Transportation Federal Safety Standards"
   2. ANSI/ASME B31. 8-1982, "Gas Transmission and Distribution Piping Systems"
   3. "ASME Guide for Gas Transmission and Distribution Piping Systems - 1983"

C. Liquid Petroleum Pipelines
   1. ANSI/ASME B31. 4-1979, "Liquid Petroleum Transportation Pipeline Crossing Railroads and Highways", API Recommended Practice 1102
   2. Title 49, Code of Federal Regulations, Part 195, "Transportation of Hazardous Liquids by Pipelines"

D. Cathodic Protection - the National Association of Corrosion Engineers (NACE) "Recommended Practice, Control of External Corrosion in Underground or Submerged Metallic Piping Systems", NACE Standard RP-01-69.

Future Widening and Construction

Anticipating future highway widening may not always be possible. If it is known that a highway will be widened in the future, however, pipeline protection should be provided to account for such widening. Situations arise when highway widening is planned for an existing pipeline crossing site where no provisions were made in the protective measures for future widening. A decisions is then required on whether to extend the pipeline protection in the same manner that exists; modify the entire crossing; modify only the pipeline under the widening; or widen the roadway without modifying the crossing. The utility's recommendations for pipeline protection of the widening should be reviewed by the highway agency. The same factors used for a new crossing evaluation should be used in a widening evaluation. The costs of modifying or replacing the existing crossing should also be considered.

Future repair, replacement, or maintenance of pipelines should be a factor in a utility's crossing application. Distribution pipelines are more likely to be modified to provide new service. Casing pipes, tunnels, or galleries may be beneficial in such situations to facilitate modifications or expansions. Transmission mains, on the other hand, cannot be easily taken out of service and are generally larger in physical size. Pipeline operators usually do not remove and replace transmission pipes crossing highways. Instead, they generally bore or jack a new crossing and abandon the old crossing. For such crossings, using an encasement pipe sleeve for the sole purpose of facilitating future removal and replacement is inappropriate.

PROTECTIVE MEASURES

The previous section of these guidelines discussed factors to consider in the selection of methods for providing additional pipeline protection at highway crossings. Various means of providing such protection were also mentioned including encasement pipes, concrete encasement, cathodic protection, cradles or walls, protective slabs, thickened wall pipe, tunnels or galleries or leakproof joints. A description of these methods and important characteristics of each are noted below.

Sleeves

Sleeves are encasement pipes, tunnels, or galleries for carrier pipes under highways. The longer pipe, tunnels, or galleries are used under highway crossings in many situations and are appropriate for a variety of transported materials, consequences, and potential damage causes. Steel, reinforced concrete, plastic or cast iron encasement pipes may be used with either trenched or untrenched construction. Steel pipes are predominantly used in untrenched construction. Galleries of precast or cast-in-place concrete require trenched construction, while tunneling is a specialized method of untrenched construction.

Encasement pipes have been used extensively for pipeline crossing protection. Steel pipes are suitable for untrenched construction, as shown in Table A-1, which describes various untrenched construction methods. Encasement is especially useful when jacked or bored installations of coated carrier pipes may cause damage to the carrier pipe coating.

Some controversy exists over the use of encasement for highway crossings as many highway agencies require their use or the provision of suitable equal protection as recommended in the *AASHTO Guide.* Many pipeline operators believe casings are unnecessary or less suitable than other protection methods for certain situations. Pipeline operators' objections to casing use have been because of the higher cost of casing and problems with cathodic protection systems of steel casing pipes. More recent experience with uncased crossings, rather than the information originally incorporated in the *AASHTO Guide,* suggests encasement is often not the best alternative for pipeline protection of highway crossings.

When encasement pipe is used for a pipeline crossing, several points must be considered. These are:

- Rigid versus flexible casing—flexible metal casing may cause loss of support to pavements. Rigid cast iron or reinforced concrete casings, however, are not customary practice for use with steel carrier pipes that are usually used for high pressure gases or required by Federal regulations for hazardous liquids.
- Internal diameter of casing—must be large enough to facilitate installation of carrier pipe and prevent external loads from being transmitted to the carrier pipe. API recommends that the casing pipe should be at least two nominal pipe sizes larger than the carrier pipe (*4*). AWWA recommends that the casing pipe for ductile-iron carrier pipe be 6 to 8 in. larger than the outside diameter of pipe bells (*13*). AWWA also recommends an inside clearance of at least 2 in. greater than the maximum outside diameter of pipe bells, skids, or cradle runners.
- Cathodic protection—metal casing pipes can defeat cathodic protection systems for carrier pipes and lead to corrosion and failure of the carrier pipe.
- Casing seals—ends of casing pipes should be sealed to prevent flowing water and debris from entering the annular space between the casing and the carrier pipe. Foam filled annular spaces can also protect the space and prevent water from flowing.

Tunnels or galleries provide many of the advantages of encasement pipes. They protect carrier pipes from loads and in case of leakage convey materials from underneath the highway traveled way.

Even though tunnels and galleries are often relatively more expensive than other protection methods, they do offer some advantages. For example, several utilities can be placed in a tunnel or gallery. If there are no conflicts with placing different utilities in close proximity to one another, the need for multiple easements, construction, and maintenance activities can be combined in a single crossing. Also, tunnels or galleries can be constructed to allow an increase in utility sizes, the addition of utilities in a crossing, or as a means of inspecting the utilities in the crossing.

Concrete Encasement

Concrete encasement provides additional protection suitable for many crossing situations. Encasement methods using concrete include grouting, boxing, capping, and jacketing.

Grouting along with jacketing are the only concrete encasement methods suitable for untrenched construction. When boring or jacking is used with pipe, there is often a space between the carrier pipe and adjacent soil. This space can be filled with grout by pumping grout material into the space or void. When the grout hardens, it provides additional protection from corrosion and loads around the carrier pipe and helps prevent settling of the carrier pipe and the highway subgrade. The grout does not protect pipe coatings from damage during installation when it is placed after the pipe is bored or jacked. Because placing grout is not a precise operation, the grout may not cover all such damaged areas.

Boxing is the placing of concrete around the entire carrier pipe. This method provides full protection from dig-ups, loadings, settlement, and corrosion. Trenched construction is required.

Jacketing is the placing of concrete around the pipe prior to boring or jacking. Many configurations are possible for jacketing. An example of a design developed and used in numerous highway crossings is shown in Figure A-8. In this example, thicker wall pipe is coated with a double coat of asphalt or coal tar. Primer, enamel, and fiberglass wrapping may also be used as insulation. A 1-in. thick concrete jacket reinforced with wire mesh is applied outside the asphalt or coal tar coating. The pipe is then placed by boring, keeping the annular space between the pipe and hole to a minimum. The space is then filled with urethane foam to prevent water channelization along the pipeline and to mitigate the potential for settlement around the pipe.

Partial Concrete Encasement

Cradling is the placing of a slab as a base for pipe. This method does not provide full protection from dig-ups, loadings, or corrosion, but it does provide protection from settlement damage. Because the method is used with trenched construction, pipe coating damage is minimized.

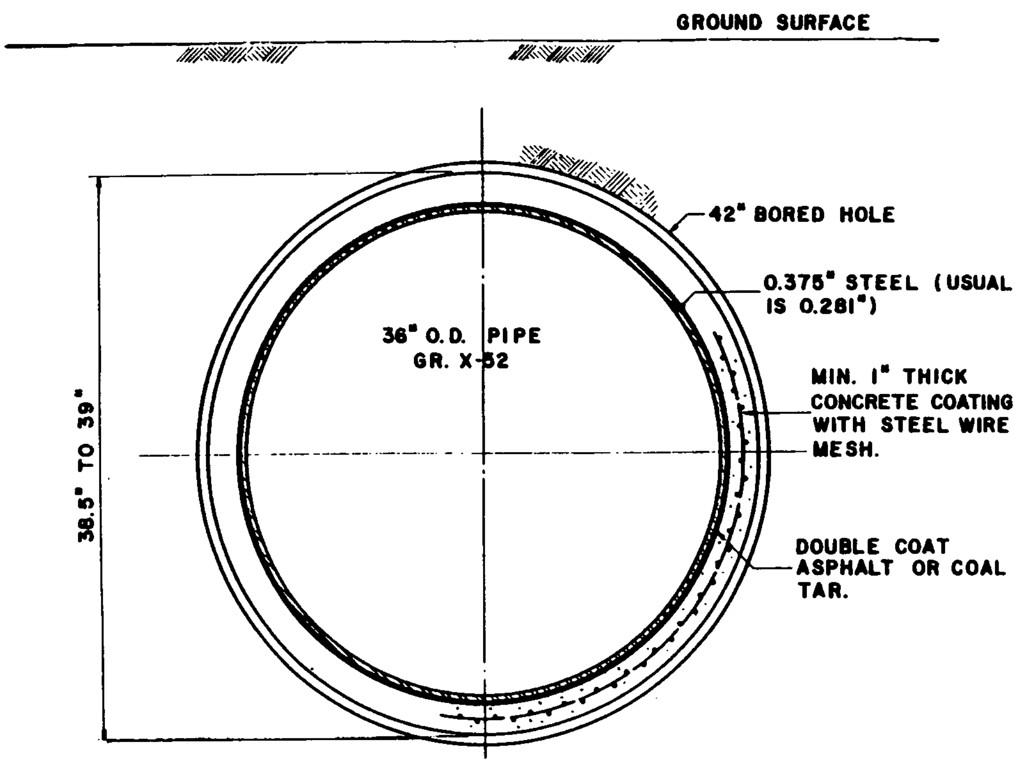


Figure A-8. Jacketed pipeline crossing. (From Ref. 12)

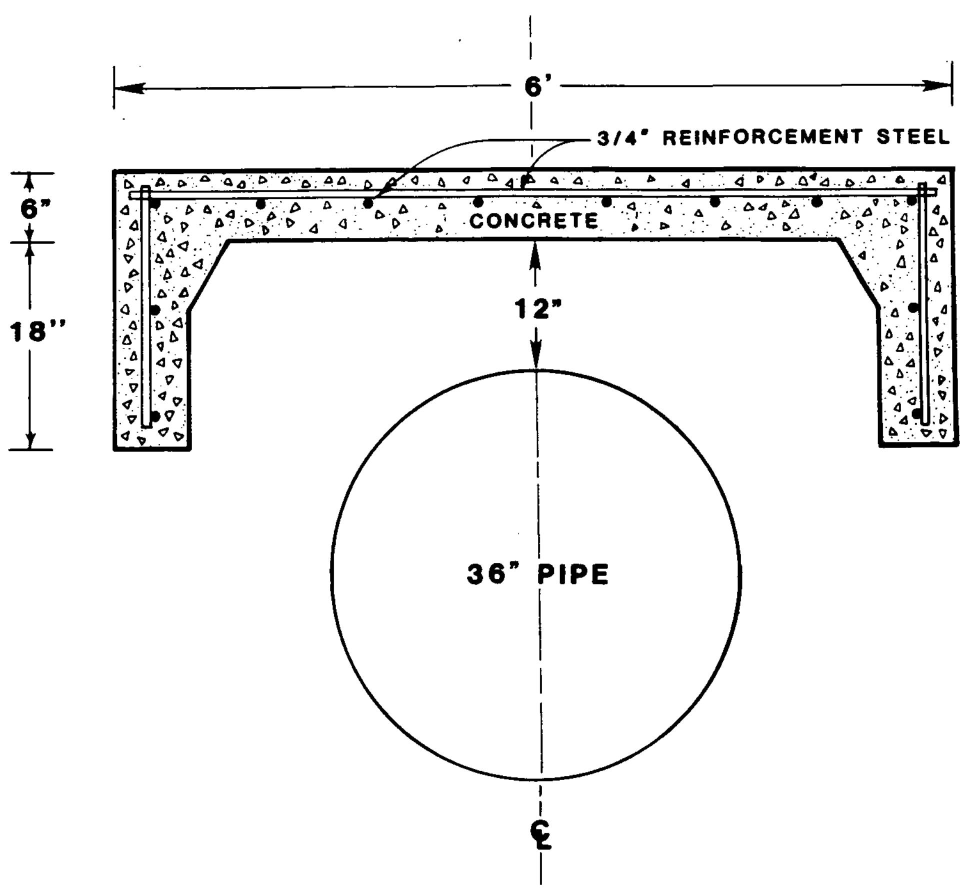


Figure A-9. Protective slab.

Walling is the placing of concrete on the sides of pipe in contact with the pipe. This provides more protection than cradling from dig-ups and corrosion, but not full protection that other methods provide.

Concrete Protective Slabs

Capping is the placing of a slab in contact with the top of the pipe. This method provides good protection from loadings and dig-ups.

A protective slab is similar to a concrete cap. However, the slab is not in contact with the carrier pipe and "floats" above the pipe. The slab can be precast or cast in place. An example of a protective slab is shown in Figure A-9. Such slabs do not provide protection from corrosion or settlement, but they provide excellent protection from loads or dig-ups by construction or maintenance equipment. Trenched construction is required.

These methods may be used for protection of the pipeline in the area between the traveled way and the right-of-way limit, even if trenched construction is not allowed in the traveled way. The slab or cap would thus provide protection from dig-ups in the area most likely to be damaged by construction or maintenance work. Damage to the roadway pavement can be eliminated and traffic disruption limited during construction.

Cathodic Protection

Cathodic protection systems are devised to reverse the natural flow of current from the pipeline to the soil. This natural current strips electrons from metallic atoms of the pipeline and corrosion results. In a cathodic protection system, a direct current from the surrounding soil to the metallic surface is introduced. This direct current can be from sacrificial anodes that are usually an alloy of zinc or magnesium, spaced along the pipe and connected to each other by lead wires. Such a system is known as a galvanic system for the galvanic couple formed between the anode and metal pipe which causes current to flow. Another means of introducing a current is called an impressed or induced current system. Low voltage direct current is either converted from conventional alternating current by a rectifier or supplied by a battery. Current flows from anode materials through the soil to the surface of the metallic pipe. Current is then collected from the pipe surface by wires that carry it back to the rectifier or battery. Figure A-10 illustrates an induced or impressed system.

In addition to requiring cathodic protection for metallic pipelines, the CFR requires periodic testing of these systems to ensure their proper functioning. Rectifiers must be inspected every 2 months and systems tested at least once a year, but at intervals not exceeding 15 months. If tests indicate any deficiencies in the system, remedial corrective action is required.

In addition to cathodic protection systems, coatings and wrapping are used to prevent corrosion of metallic surfaces. The CFR requires that an external protective coating:

- Is designed to mitigate corrosion of the buried or submerged component.
- Has sufficient adhesion to the metal surface to prevent underfilm migration of moisture.
- Is sufficiently ductile to resist cracking.
- Has enough strength to resist damage due to handling and soil stress.
- Supports any supplemental cathodic protection.

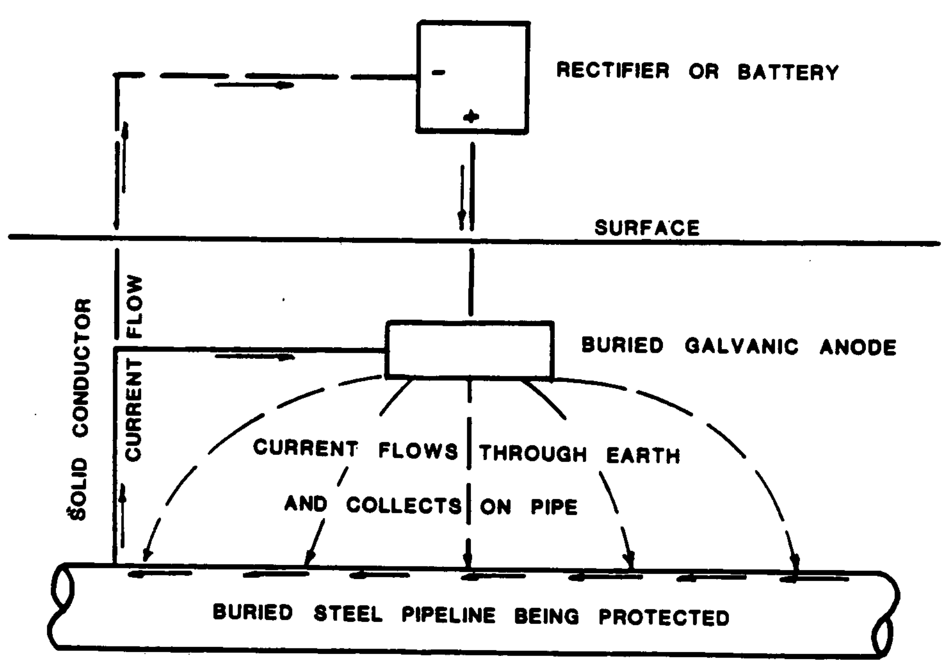


Figure A-10. Cathodic protection system. (From Ref. 14)

A wide variety of suitable coatings and wrappings is recommended by the AWWA for different applications. API recommends that coating and cathodic protection comply with ANSI/ASME B31.4 Code. Natural gas pipeline coatings must also comply with criteria specified in Title 49 of the CFR Part 192. Hazardous liquid pipeline coatings must comply with criteria specified in Title 49 of the *Code of Federal Regulations*, Part 195. The National Association of Corrosion Engineers (NACE) specifies detailed criteria for selection, testing, installation, and materials for pipeline coatings in their "Recommended Practice, Control of External Corrosion in Underground or Submerged Metallic Piping Systems," *NACE Standard RP-01-69.*

Thickened Wall Carrier Pipe

Using pipe at highway crossings with thicker walls than for cross country or normal line pipe provides additional protection for both the utility and highway. Thickened wall pipe can satisfy CFR requirements to account for dynamic traffic forces in hazardous liquid pipeline crossing design. The use of required design factors in equations for natural and other gas pipelines crossing highways will result in an increase in pipe wall thickness over cross country pipe.

Thickened wall pipe not only satisfies Federal requirements for hazardous liquid or natural gas pipelines, but also offers greater protection for all pipelines. Thickened wall pipe offers additional protection from the loss of section caused by corrosion; pressure surges; settlement stresses; and construction loads.

If thickened wall pipe is used, however, there may be an increase in the pipe rigidity over adjacent thinner walled pipe. There is some concern that this increased rigidity could affect the live load transfer to the pipe. Girth weld thicknesses will increase for thickened wall pipe with the potential for substandard welds. Because of these concerns, an alternative to thickened wall pipe is the use of higher grade steel pipe for highway crossings. Pipes of higher grade steel can provide greater strength than normal line pipe of a lesser grade steel.

Leak-Proof Joints

Pipeline joints are subject to failure because of improper welds, corrosion, or stresses. Testing of welds by nondestructive methods is required by the CFR in all highway rights-of-way for hazardous liquid and natural gas pipelines. Hydrostatic testing is also required for hazardous liquid pipelines. Such tests should ensure leak proof joints at welded sections.

Leak proof joints are also available for cast iron, concrete, or other pipe materials. The use of such joints and appropriate testing during construction can provide the additional protection required at pipeline crossings.

APPENDIX B

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