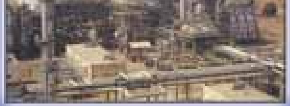
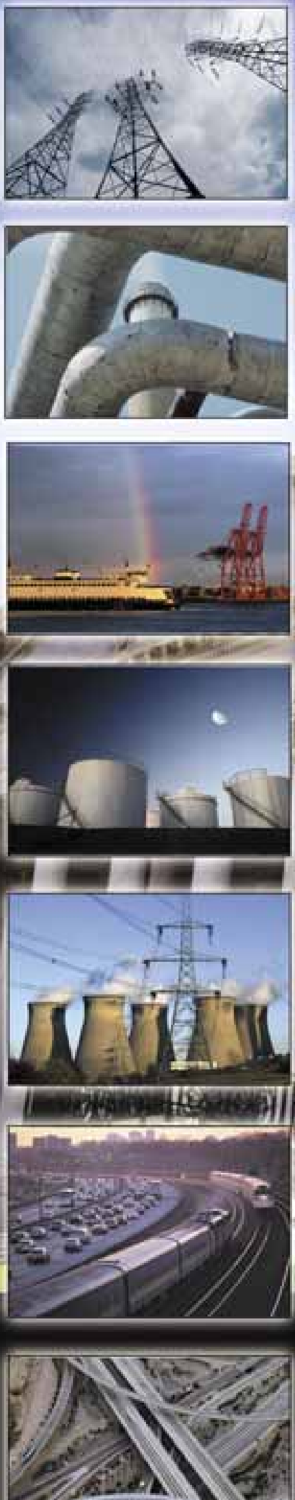


CORROSION COSTS AND PREVENTIVE STRATEGIES IN THE UNITED STATES



NACE INTERNATIONAL

Cost of Corrosion Study Unveiled

The U.S. Federal Highway Administration (FHWA) released a break-through 2-year study in 2002 on the direct costs associated with metallic corrosion in nearly every U.S. industry sector, from infrastructure and transportation to production and manufacturing. Initiated by NACE International and mandated by the U.S. Congress in 1999 as part of the Transportation Equity Act for the 21st Century (TEA-21), the study provides current cost estimates for the time and identifies national strategies to minimize the impact of corrosion.

The study, entitled "Corrosion Costs and Preventive Strategies in the United States," was conducted from 1999 to 2001 by CC Technologies Laboratories, Inc., with support from the FHWA and NACE. Its main activities included determining the cost of corrosion control methods and services, determining the economic impact of corrosion for specific industry sectors, extrapolating individual sector costs to a national total corrosion cost, assessing barriers to effective implementation of optimized corrosion control practices, and developing implementation strategies and cost-saving recommendations.

Results of the study show that the total annual estimated direct cost of corrosion in the U.S. is a staggering $276 billion—approximately 3.1% of the nation's Gross Domestic Product (GDP). It reveals that, although corrosion management has improved over the past several decades, the U.S. must find more and better ways to encourage, support, and implement optimal corrosion control practices.

The following pages feature major findings from the study, including costs by industry sector and preventive corrosion control strategies that could save billions of dollars per year. In addition to reducing expenses substantially, corrosion prevention and control is critical to protecting public safety and the environment. This important study will inevitably be reviewed and cited for decades to come.

"Corrosion Costs and Preventive Strategies in the United States"
PUBLICATION NO. FHWA-RD-01-156

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Federal Highway Administration

CC Technologies

NACE INTERNATIONAL

Corrosion—A Natural but Controllable Process

Corrosion is a naturally occurring phenomenon commonly defined as the deterioration of a substance (usually a metal) or its properties because of a reaction with its environment. Like other natural hazards such as earthquakes or severe weather disturbances, corrosion can cause dangerous and expensive damage to everything from automobiles, home appliances, and drinking water systems to pipelines, bridges, and public buildings. Over the past 22 years, the U.S. has suffered 52 major weather-related disasters—including hurricanes, tornadoes, tropical storms, floods, fires, droughts, and freezes—incurring total normalized losses of more than $380 billion[1] (averaging $17 billion annually). According to the current U.S. corrosion study, the direct cost of metallic corrosion is $276 billion *on an annual basis.* This represents 3.1% of the U.S. Gross Domestic Product (GDP) (Figure 1). Unlike weather-related disasters, however, corrosion can be controlled, but at a cost.

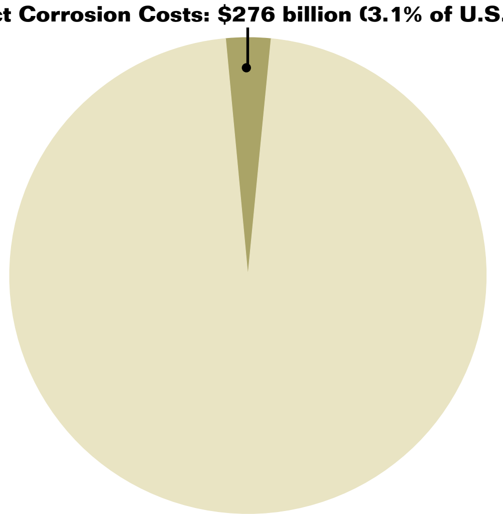
Corrosion Control Methods

Various time-proven methods for preventing and controlling corrosion depend on the specific material to be protected; environmental concerns such as soil resistivity, humidity, and exposure to saltwater or industrial environments; the type of product to be processed or transported; and many other factors. The most commonly used methods include organic and metallic protective coatings; corrosion-resistant alloys, plastics, and polymers; corrosion inhibitors; and cathodic protection—a technique used on pipelines, underground storage tanks, and offshore structures that creates an electrochemical cell in which the surface to be protected is the cathode and corrosion reactions are mitigated.

The study analyzed costs associated with each of these methods, as well as the cost of corrosion control services, research and development, and education and training. It estimated that related total direct costs were $121 billion, or 1.38% of the U.S. GDP. The largest portion of this cost (88.3%) was attributed to organic coatings. These costs do not represent the total costs associated with corrosion control methods because they do not include labor and management related to the development, design, and implementation of corrosion prevention systems—a major expense for the owner/operator.

FIGURE 1

Direct Corrosion Costs: $276 billion (3.1% of U.S. GDP)



1998 U.S. GDP ($8.79 trillion)

The impact of corrosion on the U.S. economy.

How Much Can Be Saved?

Corrosion is so prevalent and takes so many forms that its occurrence and associated costs cannot be eliminated completely. However, it has been estimated that 25 to 30% of annual corrosion costs in the U.S. could be saved if optimum corrosion management practices were employed. (See "Best Engineering Practices Saves Billions of Dollars," p. 9, and "Moving Forward—Preventive Strategies," p. 11.)

The bottom line is that the use of appropriate corrosion prevention and control methods protects public safety, prevents damage to property and the environment, and saves billions of dollars in the U.S. and worldwide.

Reference

1. T. Ross, N. Lott, "Billion Dollar U.S. Weather Disasters, 1980-2001" (Asheville, NC: National Climatic Data Center, National Oceanic and Atmospheric Administration, 2001).

Per Capita Impact of Corrosion

Corrosion affects our society on a daily basis, causing degradation and damage to household appliances, automobiles, airplanes, highway bridges, energy production and distribution systems, and much more. The cost of controlling this naturally occurring phenomenon—and costs associated with the damage it causes—is substantial. The current per capita direct cost of corrosion for U.S. residents, based on July 1, 2001, figures from the U.S. Census, is approximately $970 per person per year. This figure does not include indirect/user costs, which would essentially double that amount.

Indirect Costs

The study defined the total direct annual corrosion costs as those incurred by owners and operators of structures, manufacturers of products, and suppliers of services. Indirect costs include such factors as lost productivity because of outages, delays, failures, and litigation; taxes and overhead on the cost of corrosion portion of goods and services; and indirect costs of nonowner/operator activities. The study conservatively estimated the indirect cost to be equal to the direct cost, for a total of $552 billion. This represents 6% of the GDP.

Corrosion Costs by Industry Sector

The U.S. economy was divided into five major sector categories for analysis in the corrosion cost study, and these were further broken down into 26 sectors. The categories were infrastructure, utilities, transportation, production and manufacturing, and government. When added together, the total direct cost of corrosion for these sectors was $137.9 billion (Figure 1). This figure was then extrapolated to the total U.S. economy ($8.79 trillion) for an annual cost of corrosion of $276 billion.

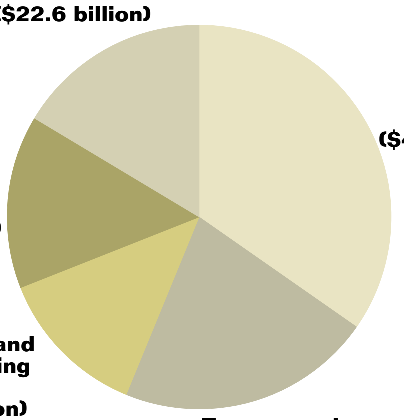
Infrastructure

The aging infrastructure is one of the most serious problems faced by society today. In past decades, corrosion professionals focused primarily on new construction—specifying materials and designing corrosion prevention and control systems for buildings, bridges, roads, plants, pipelines, tanks, and other key elements of the infrastructure. Today, as much of the aging infrastructure reaches the end of its designed lifetime, the emphasis is on maintaining and extending the life of these valuable assets.

Infrastructure in this study was divided into the following sectors: highway bridges, gas and liquid transmission pipelines, waterways and ports, hazardous materials storage, airports, and railroads. The annual direct cost in this category was estimated to be $22.6 billion (Figure 2).

FIGURE 1

COST OF CORROSION IN INDUSTRY CATEGORIES ($137.9 BILLION)



Percentage and dollar contribution to the total cost of corrosion for the five sector categories analyzed.

HIGHWAY BRIDGES

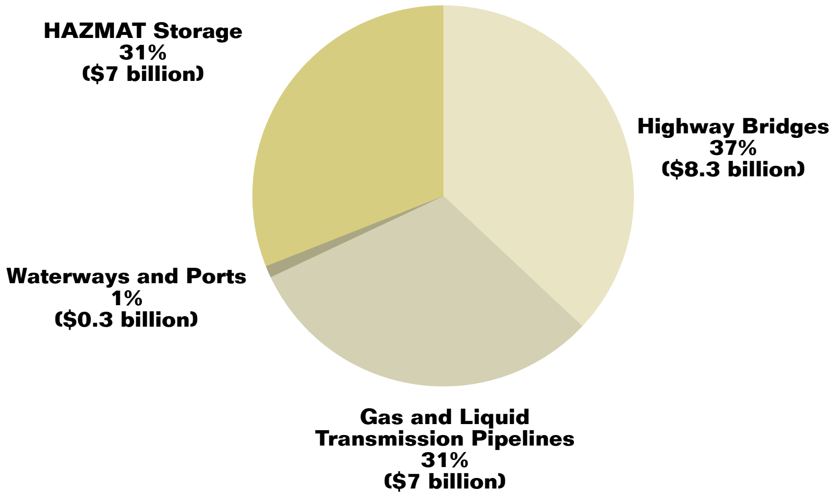
There are approximately 583,000 bridges in the U.S. Of this total, 200,000 are constructed of steel, 235,000 are conventional reinforced concrete, 108,000 are constructed using prestressed concrete, and the balance is made with other construction materials. Approximately 15% of these bridges are structurally deficient because of corroded steel and steel reinforcement. Annual direct cost estimates total $8.3 billion, including $3.8 billion to replace deficient bridges over the next 10 years, $2 billion for maintenance and capital costs for concrete bridge decks and $2 billion for their concrete substructures, and $0.5 billion for maintenance painting of steel bridges. Indirect costs to the user, such as traffic delays and lost productivity, were estimated to be as high as 10 times that of direct corrosion costs.

GAS AND LIQUID TRANSMISSION PIPELINES

Corrosion is the primary factor affecting the longevity and reliability of pipelines that transport crucial energy sources throughout the nation. There are more than 528,000 km (328,000 miles) of natural gas transmission and gathering pipelines, 119,000 km (74,000 miles) of crude transmission and gathering pipelines, and 132,000 km (82,000 miles) of hazardous liquid transmission pipelines. The average annual corrosion-related cost is estimated at $7 billion to monitor, replace, and maintain these assets. The corrosion-related cost of operation and maintenance makes up 80% of this cost.

FIGURE 2

INFRASTRUCTURE ($22.6 BILLION)



Annual cost of corrosion in the infrastructure category.

WATERWAYS AND PORTS

U.S. waterways and ports play a vital role in moving people and commerce throughout the U.S. There are 40,000 km (25,000 miles) of commercial navigable waterways that serve 41 states, with hundreds of locks that facilitate travel. Corrosion is typically found on piers and docks, bulkheads and retaining walls, mooring structures, and navigational aids. There is no formal tracking of corrosion costs for these structures; however, the study estimated an annual cost of $0.3 billion based on information from the U.S. Army Corps of Engineers and the U.S. Coast Guard. This is a low estimate because corrosion costs for harbor and other marine structures were not included.

HAZARDOUS MATERIALS STORAGE

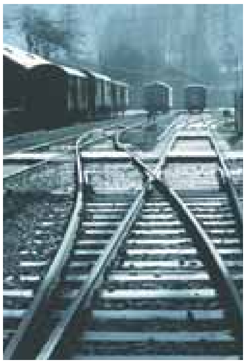
The U.S. has approximately 8.5 million aboveground and underground storage tanks (ASTs and USTs) that contain hazardous materials (HAZMAT). Government regulators have focused much attention on corrosion and other problems with these structures in recent years because of leaks that threaten public safety and the environment. Tank owners must now comply with requirements mandated by the U.S. Environmental Protection Agency for corrosion control and overfill and spill protection or face substantial costs related to cleanup and penalties. The study determined that the total annual direct cost of corrosion for HAZMAT storage is $7 billion—$4.5 billion for ASTs and $2.5 billion for USTs.

AIRPORTS

The U.S. has the world's most extensive airport system, with 5,324 public-use and 13,774 private-use airports. Airport infrastructure components susceptible to corrosion include natural gas and jet fuel storage and distribution systems, vehicle fueling systems, natural gas feeders, dry fire lines, parking garages, and runway lighting. Each of these systems is generally owned or operated by different organizations, so the impact of corrosion on airports is not known or documented and could not be quantified in the study.

RAILROADS

The U.S. railroad industry operates 274,399 km (170,508 miles) of railways throughout the country, including Class I freight, regional, and local railroads. The elements subject to corrosion include metal parts such as rail and steel spikes. However, corrosion damage to railroad components is either limited or goes unreported, so an accurate estimate of corrosion cost could not be determined.

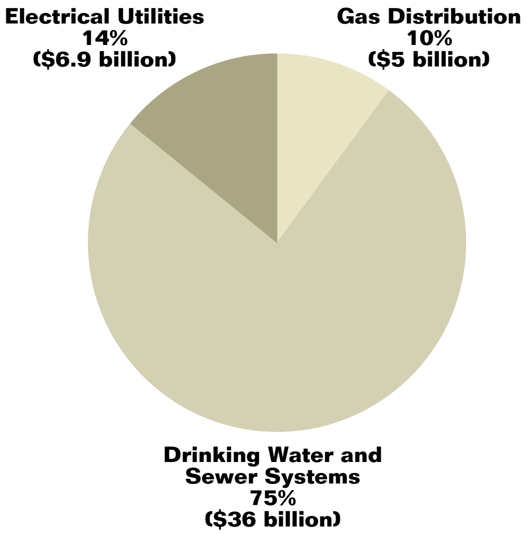


Utilities

Utilities, which supply gas, water, electricity, and telecommunications services, account for the largest portion of annual industrial corrosion costs. Direct corrosion costs total $47.9 billion. These costs are broken down into the sectors of gas distribution, drinking water and sewer systems, electrical utilities, and telecommunications (Figure 3).

FIGURE 3

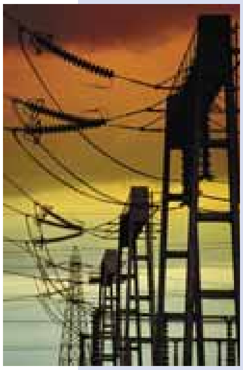
UTILITIES ($47.9 BILLION)



Annual cost of corrosion in the utilities category.

Electric Power Industry Corrosion Cost Study

The Electric Power Research Institute (EPRI) (Palo Alto, California) published a study in October 2001 (EPRI report 1004662) on the cost of corrosion in the electric power industry (see March 2002 *Materials Performance*, p. 18). Conducted by Dominion Engineering, Inc., Duke Power Co., and CC Technologies, Inc., the study broke down the cost of corrosion by component and cost category and made recommendations for optimum corrosion management strategies. The same methods were used to develop direct cost data for the nationwide U.S. study and the EPRI study; however, the EPRI study also included indirect costs. It reported total corrosion-related costs of $17.3 billion for the electric power industry vs the $6.9 billion in direct costs estimated by the U.S. study.



GAS DISTRIBUTION

The nation's natural gas distribution system has 2,785,000 km (1,730,000 miles) of relatively small-diameter, low-pressure piping that includes 1,739,000 km (1,080,000 miles) of distribution mains and 1,046,000 km (650,000 miles) of services. Many mains (57%) and service pipelines (46%) are made of steel, cast iron, or copper, which are subject to corrosion. The total annual direct cost of corrosion was estimated to be $5 billion.

DRINKING WATER AND SEWER SYSTEMS

According to the American Waterworks Association (AWWA) industry database, there are approximately 1,483,000 km (876,000 miles) of municipal water piping in the U.S. The sewer system consists of 16,400 publicly owned treatment facilities that release some 155 million m^3 (41 billion gal) of waste water per day. The total annual direct cost of corrosion for drinking water and sewer systems is $36 billion, which includes the costs of replacing aging infrastructure, lost water from unaccounted-for leaks, corrosion inhibitors, internal mortar linings, external coatings, and cathodic protection.

ELECTRICAL UTILITIES

Electricity-generating plants can be divided into seven generic types: fossil fuel, nuclear, hydroelectric, cogeneration, geothermal, solar, and wind. The majority of electrical power in the U.S. is generated by fossil fuel and nuclear supply systems. The direct cost attributed to corrosion was $6.9 billion, with the largest amounts for nuclear power ($4.2 billion), followed by fossil fuel ($1.9 billion), hydraulic and other power ($0.15 billion), and transmission and distribution ($0.6 billion).

TELECOMMUNICATIONS

The telecommunications infrastructure includes hardware such as electronics, computers, and data transmitters, as well as equipment shelters and the towers used to mount antennas, transmitters, receivers, and television and telephone systems. Towers and shelters are commonly painted or galvanized for corrosion protection. Costs are also associated with corrosion of buried copper grounding beds and galvanic corrosion of grounded steel structures. However, no corrosion cost was determined for the telecommunications sector because of a lack of information in this rapidly changing industry. In addition, many components are being replaced before failure because their technology quickly becomes obsolete.

Transportation

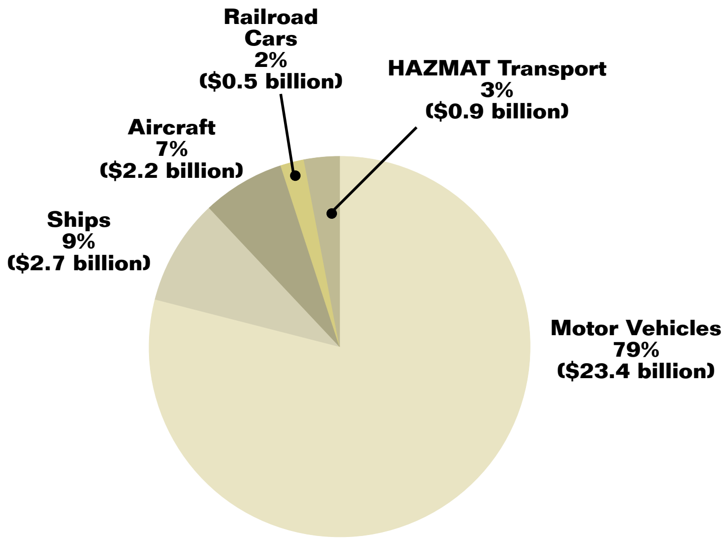
The transportation category includes vehicles and equipment, such as motor vehicles, aircraft, rail cars, and HAZMAT transport. The annual corrosion cost in this category is $29.7 billion (Figure 4).

MOTOR VEHICLES

U.S. consumers, businesses, and government organizations own more than 200 million registered motor vehicles. Car manufacturers have dramatically increased the corrosion

FIGURE 4

TRANSPORTATION ($29.7 BILLION)



Annual cost of corrosion in the transportation category.

resistance of vehicles over the past two decades by using corrosion-resistant materials, better manufacturing processes, and more effective engineering and design. The study points out that individual components could be further improved. The total annual direct cost of corrosion was estimated at $23.4 billion, with $14.46 billion attributed to corrosion-related depreciation of vehicles. Another $6.45 billion is spent on repairs and maintenance made necessary by corrosion, and $2.56 billion represents increased manufacturing costs from corrosion engineering and the use of corrosion-resistant materials.

SHIPS

The number of ships in the U.S. includes 737 vessels on the Great Lakes, 33,668 inland and 7,014 ocean vessels, 12.3 million recreational boats, and 122 cruise ships serving North American ports. The shipping industry cost of corrosion is $2.7 billion, broken down into new ship construction ($1.1 billion), maintenance and repairs ($0.8 billion), and corrosion-related downtime ($0.8 billion).

AIRCRAFT

In 1998, the combined commercial aircraft fleet operated by U.S. airlines numbered more than 7,000 airplanes. Airplanes aging beyond their 20-year design life are of greatest concern because only recent designs have incorporated significant improvements in corrosion prevention during engineering and manufacturing. Total direct annual corrosion costs are estimated to be $2.2 billion, including the cost of design and manufacturing ($0.2 billion), corrosion maintenance ($1.7 billion), and downtime ($0.3 billion).

RAILROAD CARS

There are approximately 1.3 million freight cars and 1,962 passenger cars operating in the U.S. Covered hoppers (28%) and tanker cars (18%) make up the largest segment of the freight car fleet. The transported commodities range from coal, chemicals, ores, and minerals to motor vehicles and farm and food products. Railroad cars suffer both external and internal corrosion, with a total estimated corrosion cost of $0.5 billion. This cost is divided equally between the use of external coatings and internal coatings and linings.

HAZARDOUS MATERIALS TRANSPORT

According to the U.S. Department of Transportation, there are approximately 300 million hazardous material shipments of more than 3.1 billion metric tons annually in the U.S. Bulk transport over land includes shipping by tanker truck and rail car and by special containers on vehicles. The total annual direct cost of corrosion for this sector is more than $0.9 billion, which includes the cost of transporting vehicles ($0.4 billion) and of specialized packaging ($0.5 billion), as well as costs associated with accidental releases and corrosion-related transportation incidents.

Production and Manufacturing

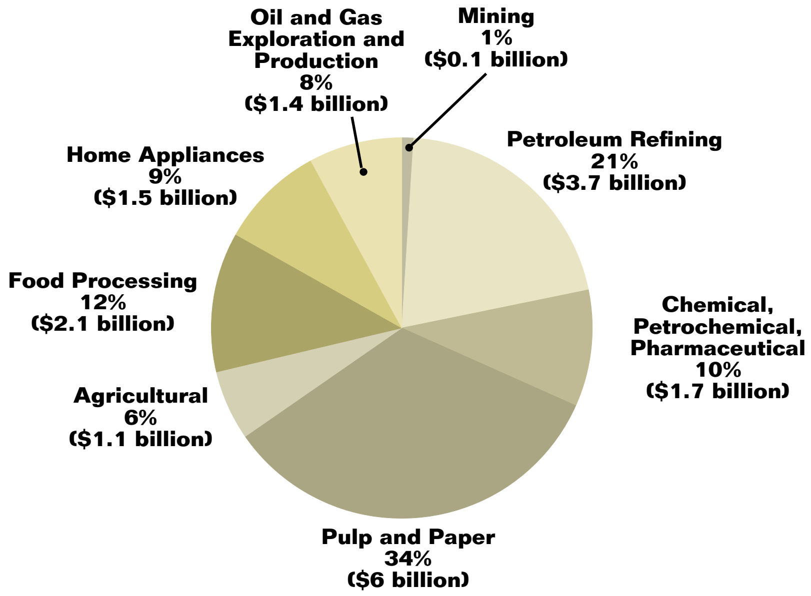
This category includes industries that produce and manufacture products of crucial importance to the U.S. economy and its residents' standard of living. These include oil production, mining, petroleum refining, chemical and pharmaceutical production, and agricultural and food production. The total annual direct cost of corrosion for production and manufacturing is estimated to be $17.6 billion (Figure 5).

OIL AND GAS EXPLORATION AND PRODUCTION

Domestic oil and gas production is considered a stagnant industry in the U.S. because most of the significant available reserves have been exploited. Direct corrosion costs associated with

FIGURE 5

PRODUCTION AND MANUFACTURING ($17.6 BILLION)



Annual cost of corrosion in the production & manufacturing category.

this activity were determined to be about $1.4 billion, with $0.6 billion attributed to surface piping and facility costs, $0.5 billion to downhole tubing, and $0.3 billion to capital expenditures related to corrosion.

MINING

Corrosion is not considered a significant problem in mining operations. The primary life-limiting factors for mining equipment are wear and mechanical damage. Maintenance painting, however, is heavily relied upon to prevent corrosion, with an estimated annual expenditure of $0.1 billion.

PETROLEUM REFINING

U.S. refineries represent approximately 23% of the world's petroleum production—the largest refining capacity in the world. The nation's 163 refineries supplied more than 18 million barrels per day of refined petroleum products in 1996, with a total corrosion-related direct cost of $3.7 billion. Maintenance expenses make up $1.8 billion of this total, vessel expenses are $1.4 billion, and fouling costs are approximately $0.5 billion annually.

CHEMICAL, PETROCHEMICAL, AND PHARMACEUTICAL PRODUCTION

The chemical industry includes those manufacturing facilities that produce bulk or specialty compounds from chemical reactions between organic and/or inorganic materials. The petrochemical industry includes facilities that manufacture substances from raw hydrocarbon materials such as crude oil and natural gas. The pharmaceutical industry formulates, fabricates, and processes medicinal products from raw materials. Annual direct costs total $1.7 billion for this sector (8% of capital expenditures). This does not include corrosion costs related to operation and maintenance—this would require detailed study of data from individual companies.

PULP AND PAPER

The $165 billion pulp, paper, and allied products industry supplies the U.S. with approximately 300 kg of paper per person each year. More than 300 pulp mills and 550 paper mills

support its production. The harsh processing environments of these facilities make corrosion control especially costly and challenging. The direct annual cost for this sector is $6 billion, calculated as a fraction of the overall maintenance costs.

AGRICULTURAL PRODUCTION

According to the National Agricultural Statistics Service, about 1.9 million farms in the U.S. produce livestock and crops. The primary reasons for replacing machinery or equipment include upgrading and damage from wear and corrosion. The corrosion cost in this industry was estimated to be $1.1 billion, based on the assumption that corrosion costs represent 5 to 10% of the value of all new equipment.

FOOD PROCESSING

The food-processing industry is one of the largest manufacturing industries in the nation, accounting for approximately 14% of total manufacturing output. Stainless steel (SS) is widely used in this industry because of food quality requirements. The total estimated corrosion cost is $2.1 billion, including SS used for beverage production, food machinery, cutlery and utensils, commercial and restaurant equipment, appliances, aluminum cans, and the use of corrosion inhibitors.

ELECTRONICS

Computers, integrated circuits, and microchips are exposed to a variety of environmental conditions, and corrosion manifests itself in several ways. It is also insidious and cannot be readily detected; therefore, when corrosion failure occurs, it is often dismissed as a product failure and the component is replaced. Although the cost of corrosion in this industry could not be estimated, it is believed that a significant part of all electric component failures is caused by corrosion.

HOME APPLIANCES

The appliance industry is one of the largest consumer products industries. The cost of corrosion in home appliances includes the cost of purchasing replacement appliances because of premature failures caused by corrosion. For water heaters alone, the replacement cost was estimated at $460 million per year, with at least 5% being corrosion-related. The cost of internal corrosion protection for all appliances includes the use of sacrificial anodes ($780 million per year), corrosion-resistant materials, and internal coatings. The annual cost of external corrosion protection with coatings was estimated at $260 million. Total annual direct corrosion costs are at least $1.5 billion.

Government

Although federal, state, and local governments own and operate significant assets under various departments, the U.S. Department of Defense was selected for analysis in the study because it strongly affects the U.S. economy. The nuclear waste storage sector was also analyzed.

DEFENSE

Corrosion of military equipment and facilities has been an ongoing problem that is becoming more prominent as the acquisition of new equipment slows down. Corrosion is potentially the number one cost driver in lifecycle costs in this sector—approximately $20 billion per year.

NUCLEAR WASTE STORAGE

Nuclear wastes are generated from spent fuel, dismantled nuclear weapons, and products such as radio pharmaceuticals. The most important design consideration for safe storage of nuclear waste is effective shielding of radiation. A 1998 total lifecycle analysis by the U.S. Department of Energy for the permanent disposal of nuclear waste in Yucca Mountain, Nevada, estimated the repository cost by the construction phase (2002) to be $4.9 billion with an average annual cost of $205 million through 2116. Of this cost, $42.2 million is corrosion-related.

Best-Practice Engineering Saves Billions of Dollars

For decades, corrosion professionals have made great strides in developing cutting-edge technologies, employing effective management practices, and increasing public awareness about the critical need for corrosion control worldwide. The U.S. corrosion cost study has determined, however, that incorporating the latest corrosion control strategies still requires widespread changes in industry management and government policies as well as additional advances in science and technology. As the following examples show, implementation of best-practice engineering in every sector could save billions of dollars in the long run.

Transmission Pipelines

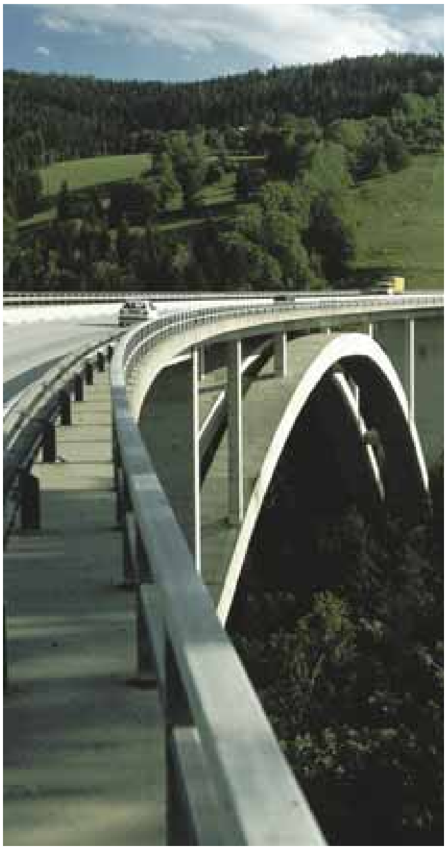
Public safety concerns have driven new regulations and corrosion control practices for gas and liquid transmission pipelines over the past few years, following a number of high-profile pipeline failures. Data management, system quantification through the use of global positioning systems, remote monitoring, and electronic equipment documents have significantly improved several areas of pipeline corrosion maintenance. The newest developments center on risk assessment strategies and pipeline integrity management programs.

The study has determined that major cost savings can be realized by developing an optimum approach that includes both pipeline inspection and corrosion prevention strategies. Inspection strategies should include in-line inspection, hydrostatic testing, and direct assessment—all currently available methodologies—depending on the pipeline conditions. By developing new and improved inspection techniques and corrosion prediction models, corrosion professionals will be able to determine inspection intervals more accurately, prioritize the most effective corrosion-prevention strategies, and, ultimately, increase the lifetime of the nation's pipelines, ensuring safe and cost-effective transport of valuable energy sources.

Highway Bridges

The dollar impact of corrosion on reinforced-concrete, prestressed concrete, and steel bridges is considerable, but the indirect costs—those incurred by users—increase expenses tenfold. For example, a traffic tie-up or detour caused by a bridge failure or its rehabilitation and maintenance can result in wear and tear on automobiles, increased gasoline use, delays in product transport, missed appointments, and other inconveniences that result in lost dollars.

A typical dilemma for bridge management is how to allocate limited funds for construction, rehabilitation, and maintenance. Funding typically comes from city, state, and federal sources that often have spending restrictions. It is therefore difficult to make optimal decisions about when and how to inspect, repair, or replace bridges while minimizing the impact on drivers. The study identifies an urgent need for the allocation of greater funding so bridge engineers can properly maintain the structures based on timely inspections. Increasing use of corrosion-resistant alloys, improved coatings, and durable concretes will further reduce the large direct and indirect expenses associated with bridge corrosion.



Water Distribution

In 2000, the Water Infrastructure Network (WIN) reported that the aging water distribution infrastructure requires major investments for maintenance and replacement of pipes and mainlines. Substantial amounts of water are lost from corroded and ruptured mains, resulting in inflated water pricing for consumers and overcapacity in water treatment plants. Corrosion professionals are striving to use economical repair and replacement methodologies while maintaining ongoing service.

Water transmission and distribution systems can be effectively protected from internal corrosion by using corrosion inhibitors in combination with pH adjusters and alkalinity control. Cement mortar linings resist corrosion in steel and iron pipes, and pipes can be externally protected with coatings and cathodic protection. These systems, when applied correctly by trained professionals, help prevent costly repairs and repaving—expenses that currently make up about 50% of water department budgets.

Unfortunately, there is a lack of complete and up-to-date information on all water systems, with limited communication among water utilities and, thus, limited awareness and implementation of available corrosion control technologies. The study recommends establishing a national effort to decrease the amount of unaccounted-for water and create a resource where agencies can obtain training and support for corrosion protection plans. It also stresses the importance of regularly scheduled corrosion inspections for water treatment facilities, water tanks, towers, and transmission and distribution systems.

Aircraft

One of the major concerns of the aircraft and airline industry is the aging of several types of aircraft beyond their design life. Airline operators have been mandating more frequent inspections and maintenance in past years in response to considerable attention from industry and the government about the safety of older planes. Although key improvements have been made in the corrosion design and manufacturing of new airplanes, including using more corrosion-resistant materials, operators should have a good corrosion control program in place throughout the life of the airplane.

The study identifies the need to develop corrosion prediction models that help define a cost-effective integrity program. Improved inspection and monitoring techniques will expand the capabilities of detecting and monitoring flaws from an early stage, preventing much bigger and costlier problems in the future.

Automobiles

Until the late 1950s, corrosion of motor vehicles was a concern largely limited to marine environments. In subsequent years, the increasing use of deicing salts for roadways and bridges caused vehicles in the snowbelt area of the U.S. to corrode and fall apart within a few years of their initial purchase. Fortunately, cars and trucks manufactured in recent decades have very little visible corrosion because of vast improvements in manufacturing and design technologies. The annual cost of corrosion is still substantial, however, and more can be done to reduce this cost.

According to the study, automobile manufacturers should build on the history and success of today's corrosion-resistant vehicles. Every new vehicle should be designed to minimize corrosion, built to meet high quality standards, and constructed of corrosion-resistant materials where appropriate. The study predicts that the competitive nature of the automobile industry ensures that a good balance between corrosion resistance and vehicle cost will probably be achieved.

Moving Forward—Preventive Strategies

This current corrosion cost study clearly reveals that, while technological advancements have provided many new ways to prevent corrosion, better corrosion management can be achieved using preventive strategies in nontechnical and technical areas. These strategies are identified as follows:

- Increase awareness of significant corrosion costs and potential cost savings.
- Change the misconception that nothing can be done about corrosion.
- Change policies, regulations, standards, and management practices to increase corrosion cost savings through sound corrosion management.
- Improve education and training of staff in the recognition of corrosion control.
- Implement advanced design practices for better corrosion management.
- Develop advanced life-prediction and performance-assessment methods.
- Improve corrosion technology through research, development, and implementation.

The U.S. continues to face critical challenges in the field of corrosion prevention and control, where aging equipment, new product formulations, environmental requirements, and strict budgets require corrosion control programs that are designed for specific situations by highly skilled professionals. By following appropriate strategies and obtaining sufficient resources for corrosion programs, best engineering practices can be achieved. Controlling corrosion requires significant expenditures, but the payoff includes increased public safety, reliable performance, maximized asset life, environmental protection, and more cost-effective operations in the long run.

U.S. Corrosion Cost Study Web Site

Developed and maintained by CC Technologies, Inc., the Cost of Corrosion Web site features a summary, corrosion cost details by sector and corrosion control method, recommendations, a slide presentation, downloadable PDF files of the report, and more at www.corrosioncost.com.

Ordering the U.S. Report

To obtain a copy of "Corrosion Costs and Preventive Strategies in the United States," Report FHWA-RD-01-156, contact the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161; 703/605-6000; www.ntis.gov. A tech brief is also available as Report FHWA-RD-01-157. A limited number of copies are available from the R&T Report Center, phone: +1 301/577-0818; fax: +1 301/577-1421.

About the Study Participants

The U.S. FHWA commissioned the corrosion cost study through its Turner-Fairbank Highway Research Center. Turner-Fairbank coordinates a program of innovative research, development, and technology that addresses the safety, efficiency, and operation needs of the national highway system. www.tfhrc.gov.

CC Technologies Laboratories, Inc., an operating company of CC Technologies, conducted the study. The engineering, research, and testing firm specializes in corrosion, corrosion control, and pipeline and facility integrity services. www.cctechnologies.com.

NACE International, the technical society for corrosion professionals worldwide, sponsored the study. With approximately 17,000 members, the NACE mission is to provide education and communicate information to protect people, assets, and the environment from the effects of corrosion. www.nace.org.

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