Interior Coatings in Potable Water Tanks and Pipelines

Coal Tar Based Materials and Their Alternatives

The MITRE Corporation

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ABSTRACT

This report discusses the use of coal tar based coatings and their alternatives as protective linings in potable water pipelines and storage tanks. The report includes descriptions of the various coatings, and presents information on their cost, extent of use, and problems associated with their application.

ACKNOWLEDGMENTS

The authors wish to express their appreciation to the following persons at the Mitre Corporation for their most helpful suggestions and assistance in preparation of this report: Dr. Lydia M. Thomas, Dr. Stephen H. Lubore, Dr. Paul Clifford, and Pamela Miller. Special thanks go to Mr. J.E. Carvlin and Mr. Henry Stoner and their colleagues at Koppers Company for their review and constructive comments. We gratefully acknowledge the cooperation and courteousness of the numerous persons in government and industry who responded to our queries. Without their cooperation this report would not have been possible.

TABLE OF CONTENTS

	Page
LIST OF TABLES	viii
GLOSSARY	ix
EXECUTIVE SUMMARY	xi
1.0 INTRODUCTION	1
2.0 COAL TAR BASED PRODUCTS	3
2.1 Coal Tar Based Coatings Used in the Potable Water Supply Industry	3
2.1.1 Hot Applied Coal Tar Enamel	5
2.1.2 Cold Applied Coal Tar Paint	7
2.1.3 Cold Applied Tasteless and Odorless Coal Tar Paint	8
2.1.4 Coal Tar Epoxy Paint	8
2.1.5 Coal Tar Urethane Paints	11
2.1.6 Coal Tar Emulsion Paint	11
2.2 Importance of Coal Tar Based Products to Producing Industry	12
3.0 ALTERNATIVES TO THE USE OF COAL TAR BASED LININGS IN POTABLE WATER DISTRIBUTION SYSTEMS	15
3.1 Water Supply Industry Proferences for Protective Linings in the Water Distribution System	24
3.2 Comparison of the Cost of Alternative Protective Lining Systems	30
4.0 UTILIZATION OF COATING MATERIALS	36
4.1 Application Methods	36
4.2 Problems Associated with the Application of Coatings	39
5.0 TOXICOLOGICAL CONSIDERATION OF THE MATERIALS USED AS LININGS	44
5.1 Compounds Identified in Potable Water and Attributed to the Use of Lining Materials	45
5.2 Amelioration of Potential Toxicological Problems	53

TABLE OF CONTENTS

		Page
6.0 CONCLUSION AND RECOMMENDATIONS		54
BIBLIOGRAPHY		56
APPENDIX A	DESCRIPTION OF NON-COAL TAR BASED LINING SYSTEMS	65
APPENDIX B	TYPICAL COATING CHARACTERISTICS	75
APPENDIX C	FDA LIST OF APPROVED POTABLE WATER TANK LININGS	93
APPENDIX D	APPLICATION PROCEDURES FOR PIPE AND TANK LININGS	101
APPENDIX E	DIRECTIONS FOR DETERMINING THE WATER EXTRACTABLE SUBSTANCES FROM A POLYMERIC OR RESINOUS WATER CONTACT SURFACE	119

LIST OF TABLES

Table Number		Page
2-1	PARTIAL LIST OF MANUFACTURERS OF COAL TAR BASED PAINTS	14
3-1	COMPARISON OF ALTERNATIVE WATER SYSTEM LININGS WITH RESPECT TO SELECTED VARIABLES AFFECTING THEIR USE	20
3-2	PIPE USED IN U.S. WATER SUPPLY DISTRIBUTION SYSTEMS BY UTILITIES SERVING OVER 2,500 PERSONS	23
3-3	COMPARISON OF THE COST OF CONSTRUCTION OF WATER TANKS BY MATERIAL OF CONSTRUCTION	25
3-4	TABULATION OF VARIOUS ESTIMATES OF THE PERCENTAGE OF NEW WATER TANKS LINED WITH A GIVEN PAINT SYSTEM	29
3-5	ESTIMATES OF THE COST OF APPLYING SELECTED LININGS TO POTABLE WATER TANKS BY SOURCE	31
3-6	COST ESTIMATES FOR APPLYING SELECTED LININGS TO POTABLE WATER TANKS	32
4-1	BLOWER CAPACITIES REQUIRED TO MAINTAIN VAPOR CONCENTRATION WELL BELOW LOWER EXPLOSIVE LIMIT	41
5-1	ESTIMATED CONCENTRATIONS OF COMPOUNDS DETECTED IN THE WATER IN THE BAYOU CASOTTE GROUND STORAGE WATER TANK	46
5-2	COMPOUNDS DETECTED IN THE WATER SAMPLES OBTAINED IN PORTLAND, OREGON	49
5-3	ALTERNATE SOURCES OF THOSE COMPOUNDS IDENTIFIED IN THE BAYOU CASOTTE GROUND STORAGE WATER TANK	50

LIST OF TABLES

Table Number		Page
5-4	ATMOSPHERIC CONCENTRATIONS REPORTED FOR THOSE COMPOUNDS IDENTIFIED IN THE BAYOU CASOTTE GROUND STORAGE WATER TANK	51
5-5	QUALITATIVE AND QUANTITATIVE LEACHING EVALUATIONS CURRENTLY IN PROGRESS	53

GLOSSARY

Acronyms

AISI	American Iron and Steel Institute
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
NACE	National Association of Corrosion Engineers
SPCC	Steel Structures Painting Council

Terms

Alligator	A rippling appearance
Asphalt	A brown to black solid or semisolid mixture of non paraffinic hydrocarbons which occur naturally and which are also obtained as a residue from petroleum refining processes
Barytes	Barium sulfate
Cathodic protection	The use of direct current electricity from an external source to oppose the discharge of corrosion current
Coal tar pitch	A dark brown to black residue from the distillation of coal tar ranging from a sticky mass to a brittle solid depending on the degree of distillation
Destructive distillation	The heating of material such as wood, coal oil shale and residual oil in an inert atmosphere at a temperature high enough for chemical decomposition
Enamel	A paint that forms a smooth, glossy, hard coat when applied
Fractional distillation	A process of separating components of a volatile mixture by continuous counter current contact of a liquid phase and a vapor phase so that the vapor

	phase is continuously enriched in the more volatile component and the liquid phase is simultaneously enriched in the less volatile component
Keystone	Wedge-shaped pieces that form when a concrete lining is cracked
Light oil	A clear, yellow-brown oil somewhat lighter than water and containing varying amounts of coal gas products with boiling points ranging between 40°C and 200°C
Penetration	A measure of hardness or softness of coal tar enamel by ASTM test method D-5
Pig	A brush, swab, or scraper device that is pushed or pulled through a pipe, usually for the purpose of cleaning the pipe
Slot-type coke oven	A coke oven designed and operated to permit collection of the volatile material from coal during the coking process and characterized by a narrow, long and tall coking chamber
Softening point	Temperature at which the viscosity of coal tar enamel is 1×10^6 centistokes when tested in accordance with ASTM test method D-36
Talc	Hydrous magnesium silicate
Thixotropic	The property exhibited by certain gels of becoming liquid when stirred or shaken

EXECUTIVE SUMMARY

Under the Food Drug and Cosmetic Act, the FDA has the responsibility for determining the appropriateness of the use of materials that contact food, which may include potable water; the U.S. Environmental Protection Agency (EPA) has been providing informal advice regarding the suitability of coating materials used to line potable water tanks and pipelines. Coal tar and petroleum based coatings are widely used by the water supply industry to protect iron and steel from corrosion. These coatings have been considered safe for contact with potable water; however, increasing awareness of the presence of trace organic contaminants in drinking water provided the impetus for a reevaluation by the EPA of the suitability of these coatings for this purpose. Mitre/Metrek was requested to provide some of the background information which the EPA would need as input to an evaluation of the safety of coatings used for potable water system contact surfaces.

Coal tar coatings have been used in the United States to provide corrosion protection to the interior of steel potable water pipelines and to the interior of steel potable water storage tanks since 1912. The coal tar coatings are made by combining coal tar pitch with other material to make a coating with the properties desired for particular service conditions. The pitch imparts the properties of water impermeability, good adhesion, and protection against attack by biological organisms.

There are two types of coal tar coatings, hot applied and cold applied. The hot applied coating is formulated as an enamel by combining the coal tar pitch with coal, coal tar base oil and talc. By altering the proportions of the various ingredients, the properties of the coating can be adjusted to desired specifications. Cold applied coal tar coatings are combinations of coal tar pitch and suitable solvents or synthetic resins. The cold applied coal tar coating systems include cold applied coal tar paint, cold applied tasteless and odorless coal tar paint, coal tar epoxy, coal tar urethane, and coal tar emulsion.

Hot applied coal tar enamel is widely used to protect the interior and exterior of buried water mains and the interiors of water storage tanks. It is very durable, having a reported service life in excess of 50 years. Thus, it requires very little maintenance. The cold applied coal tar coatings are not as durable as the hot applied enamel but are more convenient to apply. Therefore, they are often used for above ground structures and the interiors of water storage tanks where maintenance is less difficult.

Approximately 685,000 miles of water pipe have been installed in the U.S. by those water utilities which serve a minimum of 2500 persons. A steady annual increase of approximately 2 percent in the quantity of inservice piping is the result of new water pipe installation. Slightly less than 6 percent (i.e., 39,400 miles) of the

water pipe that is currently installed is steel, and it is believed that between 50 and 80 percent of this steel pipe is lined with hot applied coal tar enamel. Other linings that have been used in steel pipe are cement mortar, baked phenolic, polvinyl chloride, polyethylene, vinylidene chloride copolymer, tetrafluoroethylene and neoprene. Approximately 75 percent (on a mileage basis) of the water pipe that is currently in place is cast iron, which is usually lined with cement mortar. The cement mortar lining in cast iron pipe is given a seal cost of bituminous material to aid in curing of the cement mortar and to inhibit soft water decalcification. The seal coat is usually a petroleum derived asphalt paint. Asbestos cement pipe accounts for approximately 13 percent (on a mileage basis) of water pipe in place. Materials used for the remaining water pipe are reinforced concrete, plastic, iron, copper and wood.

There are approximately one-half million steel water storage tanks in the U.S., ranging in capacity from 50,000 gallons to 10 million gallons. A number of different linings have been used to protect the interior of these tanks from corrosion including several which are coal tar based, and vinyl, epoxies, wax, zinc rich, metallic zinc, chlorinated rubber, and phenolic based linings.

Over 1000 new steel water tanks are constructed each year. Because conflicting estimates were obtained from industry contacts of the percentage of these tanks being lined with coal tar based coatings, no accurate estimates can be given. Koppers Company, the

major supplier of coal tar coatings to the industry, estimates that 19 percent of new steel water tanks are lined with coal tar. In some locations, 100 percent of the steel water tanks are lined with hot applied coal tar enamel (Seattle, Washington; California Water Service).

An estimated 10,000 tons of hot applied coal tar enamel, representing somewhat less than 10 percent of the total market for the product, were sold to the water supply industry in 1976. The value of the coal tar enamel to the producers was $1,500,000. The dollar value of solvent based cold applied coal tar paint used in new water supply industry construction in 1976 was about $225,000.

In recent years, the use of hot applied coal tar based linings for water distribution systems has been declining. Shortages in the availability of qualified applicators, increasing costs, difficulties in the ability to control worker exposures during application, and increasing concern of the potential effects on human health have all contributed to the decline in usage of hot applied coal tar based materials for this purpose.

A variety of alternatives to the hot applied coal tar based linings have been developed and are finding increasing application. Cement mortar (not normally seal coated) or polyamide cured epoxy paint are commonly used as alternatives to hot applied coal tar enamel for lining steel water pipes. The AWWA standard for painting

and repainting steel water storage tanks includes a number of non-coal tar based systems (e.g., vinyl paints, metallic zinc, wax, chlorinated rubber, and epoxy). In addition, there are numerous proprietary paint formulations considered suitable for use in water immersion service which have received approval for use as linings in potable water storage tanks by local, state, and federal agencies.

Personal preferences and cost play a part in the selection of a particular lining for water tanks. Many different linings are being used nationally, however, some localities still prefer coal tar enamels. Although the initial application cost of most of the alternative coatings is comparable to that of hot applied coal tar enamel, their life time cost (e.g., including maintenance and repairs) ranges from 2.5 to 11.5 times that of the cost of coal tar enamel, primarily due to the necessity for more frequent recoating.

Although it is apparent that obvious choices in a lining material may be indicated by ease of application, frequency of need for repair, and/or lifetime costs, there is no suitable and comprehensive method for evaluating the relative health risks of the various available materials. Concern of risks to public health has escalated with repeated determinations of the presence of organics in trace quantities in potable water. There are data that provide evidence for leaching of organics into water from coal tar based coatings used for water system contact surfaces. The data are limited, however, and are not indicative of leaching rates, the constancy of those

rates, the effects of water quality on leaching rates, the solubilities of the leached compounds, the extent and products of decomposition of the leached compounds, the ultimate concentrations to which the general public might be exposed via drinking water, or the interactions between the compounds. Due to the inadequacies of the data it is not possible to prudently estimate the relative health risks inherent to the various materials utilized for potable water system contact surfaces. In addition to the health risks to the general public, there are occupational health risks associated with application of the linings (e.g., vinyl paints may contain vinyl chloride monomer a known carcinogen; urethane paints and epoxy paints contain ingredients that are irritants to some people; exposure to zinc oxide fumes during application of metallic zinc coatings can cause metal fume fever; some materials contain solvents which are central nervous system depressants).

New paint products and formulations are regularly introduced to the market, and their suitability for use on potable water contact surfaces is currently based primarily on durability under long-term immersion conditions and the results of an extraction test. The extraction test is not designed to qualitatively or quantitatively determine the individual compounds that are leached into the water nor does it provide values for the parameters of interest mentioned

previously. Until such time as these data are available and applicable toxicological information is compiled it would be difficult to proceed with a comprehensive assessment of the relative effectiveness/risk of the various coatings.

1.0 INTRODUCTION

Iron and steel are commonly used for potable water pipelines and storage tanks. A surface coating is applied which will protect the metal from corrosive attack and reduce rust contamination of the water. Since the coating is in contact with the potable water, it is essential that it not impart any taste, odor or toxicity to the water. The U.S. Environmental Protection Agency (EPA) has been providing informal advice to states regarding the suitability of substances which may directly or indirectly contact potable water. Coal tar and petroleum based coatings are widely used by the water supply industry to protect iron and steel from corrosion and have been considered to be safe for contact with potable water. However, increasing concern about trace organic contaminants in drinking water has caused the EPA to reevaluate the safety of these and other coatings used in potable water distribution systems.

The EPA Office of Drinking Water requested Mitre/Metrek to provide some of the background information needed to properly evaluate the safety of various coating formulations used in potable water distribution systems. In particular, information was requested regarding the following:

a. Coal tar products used, the extent of their use, their cost, and their importance to the coal tar producers and to the water supply industry.

b. The alternatives to coal tar base coatings, their cost, availability, and acceptability for contact with potable water.

c. The composition of the coatings; and an identification of substances that may be leached into the water from the coatings.

d. Problems associated with application of the coatings including application procedures, curing problems, and hazards to workers who apply the coatings.

Information for this report was obtained from the open literature, industry trade associations, manufacturers, coating applicators, municipal water engineers, U.S. government agencies, and engineering consultants.

2.0 COAL TAR BASED PRODUCTS

Coal tar is obtained by the destructive distillation of bituminous coal. In the United States, it is usually produced as a by-product of the manufacture of metallurgical coke. The tar is recovered from the coke oven gases by partial condensation. The material escaping the initial partial condensation is "light oil" and gas. The tar can be further processed by fractional distillation to yield tar acids, tar bases, naphthalene, and creosote oil. The residue remaining after distillation is commonly referred to as pitch. It is dark brown to black in color and may range from a sticky mass to a brittle solid. Most coal tar pitch made melts between 60°C and 70°C (Bureau of Mines, 1968). The pitch fraction resists penetration by water and resists deterioration by water action. These characteristics make it highly desirable for such applications as waterproofing and roofing, and for use in protective coatings for buried or submerged iron and steel structures and pipelines (Lowry, 1963). Approximately 1 million tons of pitch are sold annually in the United States for all uses (Chemical Marketing Reporter, 1976). The primary use of coal tar pitch, however, is as a binder in the manufacture of carbon electrodes which are used in the electrolytic production of aluminum.

2.1 Coal Tar Based Coatings Used in the Potable Water Supply Industry

Coal tar pitch itself is generally not suitable as a protective coating for metalwork. It softens when exposed to the sun in warm

weather. At temperatures below freezing, it becomes brittle and may crack or separate from the metal surface. Flowing water will produce ripples in the coating, creating thin spots that reduce its protective capability (Bureau of Reclamation, 1976).

The American Water Works Association has specified minimum requirements for the coal tar to be used in potable water systems. These are that "coal tar shall be produced from coal that has a minimum heating value of 13,000 Btu per pound on a moisture-and-mineral-matter free basis (ASTM test method D-388) and that has been carbonized in a slot-type coke oven at a temperature of not less than 900°C.

Coal tar coatings suitable for use as a protective coating on steel are made by combining coal tar pitch with other materials. The coating retains the impervious properties of the pitch but the undesirable properties of the straight pitch are overcome. There are six coal tar based coating systems: 1. Hot Applied Coal Tar Enamel; 2. Cold Applied Coal Tar Paint; 3. Cold Applied Tasteless and Odorless Coal Tar Paint; 4. Coal Tar Epoxy Paint; 5. Coal Tar Urethane Paint; and 6. Coal Tar Emulsion Paint. Within each of these generic coal tar coating designations, numerous formulation variations are possible. Some of these variations may be suitable in a particular service for which other variations are not suitable. Thus, for example, a manufacturer may sell a number of different coal tar epoxy paints but only a few may be suitable for use in potable

water. Each of the six generic coal tar coatings have been available in formulations considered suitable for potable water service at one time. Some of them may no longer be sold. Koppers Company (1978) stated that they did not know of any coal tar urethane currently for sale.

2.1.1 Hot Applied Coal Tar Enamel

The hot applied coal tar enamel used in water works systems conforms to the C-203 specification of the American Water Works Association (AWWA, 1964; 1973; 1978). The enamel is manufactured by dispersing coal in a mixture of coal tar pitch or refined coal tar and high boiling coal tar base oil at a temperature between 250° and 350°C. The product can be adjusted to any desired softening point/penetration specification by varying the proportions of the three ingredients. The enamel is strengthened by the incorporation of about 30 percent by weight of talc (Harris et al., 1975). The enamel specified as a lining in steel water pipe is usually highly plasticized and has the characteristics shown in Appendix B, Table B-1 (Bureau of Reclamation, 1976; Fair, 1956).

Hot applied coal tar enamel was first used in the United States for lining steel water pipelines in 1914 by the City of New York (Kinsey, 1973). A water storage tank is reported to have been enameled with coal tar in 1912 in southern California (Hayes, 1970). Inspection of coal tar enameled pipes and tanks after many years of service in water supply systems showed no coating failures when the

material was properly applied (Hayes, 1940; Garrett, 1946). A service life in excess of 50 years can be expected for the lining (Bureau of Reclamation, 1976).

Coal tar enamel has a service life in excess of 50 years primarily because of its resistance to absorption of water. Curves of water absorbed by the coal tar enamel per square foot of surface show almost no increase in water absorption beyond about 0.2 grams of water absorbed per square foot after 20 days immersion (Fair, 1956). This characteristic of coal tar enamels is not changed by addition of fillers to improve other properties of the enamel (Hayes, 1940).

Other advantages of hot applied coal tar enamels are that they have good erosion resistance and silt or small amounts of sand in the water will not erode the lining. Algae and other growths do not build up on coal tar enamel surfaces. The lining remains smooth and therefore the carrying capacity of the pipe does not diminish over time (Garrett, 1946).

Some disadvantages of the hot applied coal tar enamel are:

- The thickness of the lining (.094 inches) reduces the carrying capacity of the pipe over what it would be if a thinner liner were used. (The available cross-sectional area of a 20 inch pipe is reduced by 2 percent (Cook, 1977).)

- The enamel is easily damaged by welding heat which causes the lining to char and peel off on each side of the weld. This results in the dangerous and difficult job of repainting the area with hot coal tar (Cook, 1977).

- In below freezing weather, great care must be taken in handling the pipe because of increased brittleness of the coating.

- If an empty enamel lined pipe is exposed to warm weather and sunlight, it may shrink and harden. The enamel may then develop cracks and the embrittlement may be the cause of later damage during the handling of the pipe (Bureau of Reclamation, 1976).

- In storage tanks, where part of the enamel coated interior may not be completely submerged, heat from the sun can cause the enamel to sag and "alligator" (Hayes, 1940).

2.1.2 Cold Applied Coal Tar Paint

The cold applied coal tar paint is made of the same components as the hot applied coal tar enamel but is liquified by the incorporation of coal tar solvents such as xylene or naphtha. It is easier to apply than the hot applied coal tar enamel because it can be brushed or sprayed on at ambient temperatures. The paint exhibits thixotropic properties and can be applied in a thick film of approximately .020 inches without sagging or running (Fair, 1956).

The coating was recommended for use in water storage tanks above the high water level by AWWA standard D 102-64 (AWWA, 1964). If used underwater, it may contribute to taste and odor. It is also considered unsuitable for open top tanks, since sunlight will crack and alligator the coating (Bureau of Reclamation, 1976; Fair, 1956). It is also unsuitable for service temperatures above 71°C (dry) or above 38°C immersed, nor below -29°C (Fair, 1956). The coating is less durable than the hot applied enamel and has a service life of between 5 and 10 years (Bureau of Reclamation, 1976). The Bureau of Reclamation no longer uses this paint system for new installations. They have replaced it with a coal tar epoxy paint which is projected to

have an immersion service life of at least 20 years (Bureau of Reclamation, 1976). The proposed revision to the AWWA standard for Painting Steel Water Storage Tanks does not include this coating (AWWA, 1977).

2.1.3 Cold Applied Tasteless and Odorless Coal Tar Paint

The tasteless and odorless coal tar based paint suitable for use in water storage tanks is composed of a selected pitch and coal tar solvents which must be free of phenol or other materials which impart taste or odor to the water. The paint contains no added filler, pigments, fibrous materials, or asphalt material. It is applied in a thin film having a dry film thickness of 0.002 inches per coat. AWWA requirements for this paint are listed in Appendix B, Table B-2 (AWWA, 1964). A new cold applied coal tar paint system is specified which is prepared by blending coal tar enamel with suitable solvents to produce a taste- and odor-free paint. The coal tar enamel used is similar to the hot applied coal tar enamel described above. The dry film thickness of each coat is approximately 0.009 inches.

The AWWA standard (AWWA, 1964) states that the system will shrink and crack if exposed to direct sunlight but gives good service when kept shaded. It can be damaged by ice and therefore should not be used where ice formation is anticipated.

2.1.4 Coal Tar Epoxy Paint

A coal tar epoxy paint suitable for use in the interior surfaces of potable water storage tanks has been specified by the Steel

Structures Painting Council (SSPC, 1973). This coating system is a two-component paint which uses a co-reacting polyamide resin* and an aromatic tertiary polyamine catalyst as curing agents. One component of the paint contains a refined coal tar pitch, a liquid type polyamide resin, a polyamine catalyst, a mineral filler, a gelling agent, and a volatile thinner. The catalyst accelerates curing of the paint and the gelling agent induces thixotropic antisag properties. The second component of the paint system is a liquid type epoxy resin which is mixed with the first component just prior to application. The mixed paint contains approximately 75 percent by volume of nonvolatile film forming solids. Each coat will give a dry film thickness of approximately 0.008 inches.

A typical composition of the coating system is shown in Appendix B, Table B-3. Specifications for the ingredients of each component and for the components are included in Appendix B, Tables B-4 through B-8.

Coal tar epoxy paints using polyamines as the sole curing agent are also available; however, one such coating which conforms to Military Specification MIL-P-23236 (dated 28 June 1962) is reported

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*The polyamide resin is a condensation product of a dimerized fatty acid and a polyamine. Fatty acids derived from the following vegetable oils have FDA approval for food contact surfaces: beechnut, candlenut, castor, chinawood, coconut, corn, cottonseed, hempseed, linseed, oiticica, perilla, poppyseed, pumpkinseed, safflower, sesame, soybean, sunflower, tall oil, and walnut (CFR 21, Part 175.300, 1977). A number of polyamines acceptable for use on food contact surfaces are also identified in the CFR. Among them are tri(dimethylaminomethyl)phenol and ethylenediamine.

to impart "highly objectionable taste and odor to water" for a period of time (not specified) after curing (Bureau of Reclamation, 1976). There are a variety of coal tar epoxy paints on the market which do not conform to either the Military Specification or the Steel Structures Painting Council specifications which may or may not be suitable for use in potable water systems. A specification for a coal tar epoxy paint system for the interior and exterior of steel water pipe has been developed by the American Water Works Association (AWWA, 1978). The specification was made available in April 1978. It is not the same specification as that published by the Steel Structures Painting Council (Kemp, 1978). The specification includes a suggested formulation for a two package epoxy primer containing non-toxic inhibitive ingredients (zinc phosphate or zinc molybdate and micaceous iron oxide). Suggested ingredients for the coal tar epoxy top coat are not given. However, characteristics of the coal tar epoxy and performance requirements are given. A minimum curing time of 7 days before placing the coated tank in service is specified.

Coal tar epoxy resin paints cure as a hard film and the service life in immersion service is anticipated to be in excess of 20 years. A coal tar epoxy resin tested by Frye (1974) was not as abrasion resistant as hot applied coal tar enamel. Coal tar epoxies chalk when exposed to sunlight.

2.1.5 Coal Tar Urethane Paints

Coal tar pitch can also be combined with polyurethane to make a coating having properties similar to coal tar epoxy paints (Bureau of Reclamation, 1976; SSPC, 1973). The polyurethanes are formed by reaction between a diisocyanate and a polyhydroxy compound. The properties of a polyurethane coating can vary widely depending on the nature of the polyhydroxy compound used and also on the type of isocyanate used. The coating can be formulated for fast or slow drying, to give a hard, flexible, or soft film, and for ability to resist chemical attack. Single component coatings can be prepared that cure by oxidation or by reaction with atmospheric moisture. Two component coatings can be prepared that use a catalyst to cure the coating in a manner similar to the epoxy paints. The abrasion resistance, hardness, and impact resistance of urethane are considered to be outstanding. In a 25-year evaluation of water tank paints (Keane, 1975), a two-coat, 0.011 inch thick coal tar urethane was reported to be giving good protection. It was rated as good as or better than some vinyl and epoxy paints. However, in the same test, a two-coat, 0.0045 inches thick coal tar urethane coating of the same manufacturer showed total failure below the water line.

2.1.6 Coal Tar Emulsion Paint

Coal tar emulsion paint is formulated by suspending coal tar pitch, inert mineral filler such as magnesium silicate, and rust inhibitor such as zinc oxide in water instead of solvent. The

advantages of coal tar emulsion paints over solvent based paints are that they will adhere satisfactorily to damp surfaces and are practically odorless (Bureau of Reclamation, 1976). They also show better resistance to sunlight. The Bureau of Reclamation has found that coal tar emulsions are not as watertight as the organic solvent coal tar coatings. They are used by the Bureau to only a limited extent for the protection of submerged metalwork (Bureau of Reclamation, 1976).

Coal tar emulsion forms a strong bond with concrete and can be used as a seal coat in cement mortar lined pipes. It acts as a curing compound and forms a waterproof membrane which protects the concrete from leaching. Koppers Company, however, states that it is not suitable for water immersion service. Typical properties of coal tar emulsion are presented in Appendix B, Table B-9. A typical coal tar emulsion consists of 23.1 percent coal tar, 29.3 percent mineral filler, and 47.6 percent water (Bricker, 1968).

2.2 Importance of Coal Tar Based Products to Producing Industry

There are two manufacturers of hot applied coal tar enamel for pipe coating and for pipe and tank lining in the United States: Koppers Company, and Reilly Tar and Chemical Company. Koppers Company also manufactures coal tar paints in addition to a number of other types of paints used to line steel water tanks. There are a number of other manufacturers and suppliers of coal tar paint products. A partial list of these manufacturers is presented in

Table 2-1. The coal tar paints of all these companies are not necessarily used by the water supply industry.

Koppers Company reported sales of 6,000 tons, or approximately $900,000 worth of hot applied coal tar enamel to the water supply industry in 1976. In addition, 15,000 gallons of a chlorinated rubber primer with a dollar value of $120,000 was used. Koppers assumed that all of the hot applied coal tar enamel went to line pipes and they assumed half of the steel pipes installed by the water supply industry in 1976 were lined with the material.

Sales of coal tar enamel to the water supply industry for tank linings represents about 10 percent ($600,000) of the business of Reilly Tar and Chemical Company. Their customers are primarily in the Southwest and Midwest.

Koppers Company estimates that they supply 80 percent of the coal tar paints to the water supply industry and that the value of these paints was approximately $450,000 in 1976. Approximately half of the market for coal tar paints is believed to be for relining existing tanks.

TABLE 2-1

PARTIAL LIST OF MANUFACTURERS OF COAL TAR BASED PAINTS

American Tar Company
1702 N. Northlake Way
Seattle, Washington

Briggs Bituminous Composition Company
2745 North Amber Street
Philadelphia, Pennsylvania

Calbar, Inc.
2620 N. Martha Street
Philadelphia, Pennsylvania

Everseal Manufacturing Company, Inc.
477 Broad Avenue
Ridgefield, New Jersey

Glidden Coatings & Resins
Architectural and Maintenance
Division of SCM Corporation
Cleveland, Ohio

Koppers Company, Inc.
1900 Koppers Building
Pittsburgh, Pennsylvania

Mass and Waldstein Company
2121-T McCarter Highway
Neward, New Jersey

Matcote Company, Inc.
P.O. Box 10762-TR
Houston, Texas

Randolph Products Company
Park Place East
Carlstadt, New Jersey

Riley Brothers, Inc.
858 Washington
Burlington, Iowa

Samuel Cabot, Inc.
Dept. 1371
1 Union Street
Boston, Massachusetts

Sterling Division of Reichold Chemicals, Inc.
1977 Ohio River Blvd.
Sewickley, Pennsylvania

Tnemec Company, Inc.
121 W. 23rd Avenue
P.O. Box 1749
Kansas City, Missouri

Tropical Paint Company
2630 Pearl Road
Medina, Ohio

Universal Protective Coatings
123-29 Jordan Street
San Rafael, California

3.0 ALTERNATIVES TO THE USE OF COAL TAR BASED LININGS IN POTABLE WATER DISTRIBUTION SYSTEMS

Alternatives to the use of coal tar based linings in potable water distribution systems include:

- the use of non-coal tar based linings;
- the use of cathodic protection;
- water conditioning, and
- the use of noncorroding construction materials.

Non-coal tar based linings - A number of non-coal tar based lining materials are currently being used by the water supply industry for iron and steel water pipelines and storage tanks. The two most commonly used non-coal tar based lining materials for steel water pipelines are cement mortar and epoxy. Cement mortar is applied as a 0.30 to 0.50 inch thick lining. Liberation of calcium hydroxide from the cement mortar inhibits rusting. Cement mortar was first used in steel water pipes in the late 1800s and some of those early pipelines were in service for the better part of a century. Cement mortar lining of steel pipes is practiced in accordance with AWWA standard C205-71 (AWWA, 1971). Among the advantages of cement mortar linings over organic lining materials (Padley, 1975) are:

- lower cost;
- lower sensitivity to variations in substrate quality;
- lower sensitivity to variations in application procedures;

- provides protection to uncoated metal at pipe joints;
- fewer coating imperfections ("holidays");
- reduced sensitivity to "holidays";
- form a pipe within a pipe which is securly held in place by a "keystone" effect even if cracked or damaged in handling; and
- surface fissures in the lining "self heal" when immersed in water (Padley, 1975; Wagner, 1974).

A disadvantage of a cement mortar lining in steel pipe is that it can fail by cracking and breaking loose in pipes subject to excessive deflection. The acceptable deflection of cement mortar lined pipe is less than that for coal tar enamel lined pipe (AISI, 1977) and for epoxy lined pipe (Cook, 1977). Another disadvantage of cement mortar linings is that the thickness of the lining reduces the available cross-sectional area and water carrying capacity of the pipe more than either coal tar enamel or epoxy. The cross-sectional area of a 20-inch inside diameter pipe lined with cement mortar is reduced by over 6 percent. A coal tar lining reduces the cross-sectional area by 2 percent and an epoxy lining reduces the cross-sectional area by less than 0.2 percent.

At the present time, cement mortar is the only material used to line cast iron and ductile iron pipe (Higgins, 1977; Dahl, 1977). American National Standard A21.4-1974 (ANSI, 1974) covers cement mortar linings for cast iron and ductile iron pipe and fittings for

water. The ANSI standard suggests the use of a bituminous seal coat over the cement mortar lining in cast iron and ductile iron pipe. The purposes of the seal coat are to aid the cement curing process by retaining moisture, and to protect the cement mortar from decalcification in soft (calcium dissolving) waters. The seal coat is most commonly, a petroleum derived asphalt based coating. The coating is about 0.001 inch thick.

The AWWA standard for cement mortar lining of steel pipes does not include the use of a seal coat as a curing aid (AWWA, 1971).

In April 1978, the AWWA published a standard for lining steel waterpipe with coal tar epoxy. Non-coal tar based epoxy systems that have been used to line water pipes include an epoxy phenolic formulation (Frye, 1974) and polyamide cured epoxy formulations (Crawshaw, 1974; Kipin, 1978; Lingle, 1978). The epoxy paints can be formulated with components that have FDA approval for food contact surfaces.

The AWWA standard for painting and repainting steel tanks for water storage (AWWA, 1964) includes several types of non-coal tar based paint systems. These are:

- Red Lead Aluminum Phenolic
- Vinyl
- Zinc Phenolic
- High Solids Vinyl
- Hot Applied Wax
- Cold Applied Wax

- Metallic Zinc

Since the original standard was published, new paint systems have been developed and have come into use while other systems have practically gone out of use. The AWWA standard is currently being revised to include some of the newer paints and to eliminate some of the lesser used paints. The latest draft of the revision omits red lead, aluminum phenolic, zinc phenolic, hot applied wax, and cold applied wax (AWWA, 1977). It adds a two-component epoxy paint system and a chlorinated rubber paint system.

Omission of a paint system from the standard does not imply that it cannot be used, only that the newer systems appear more useful. The draft revised standard includes a reference to the original standard for cold applied wax and for hot applied wax and reprints it as a "convenience" for those who may still wish to use that lining. The standard also states that "the ideal arrangement is for purchasers to cooperate with reputable paint manufacturers who will agree to furnish paint systems which have proved to perform as well as or better than those included in this standard." There are numerous paint systems on the market which have been approved for use in potable water storage tanks by local, state, and federal government agencies. While many of these conform to the AWWA standard, many others are variations of the AWWA standard systems or completely different proprietary paint systems. One of the reasons for revising the AWWA standard was to recognize that new paint systems have been

developed and that they are currently being used with satisfactory results.

A brief description of some of the non-coal tar based linings that have been used in potable water systems is included in Appendix A. Table 3-1 presents a comparison of several paint systems used to line water tanks and pipelines.

Cathodic Protection - Corrosion is an electrochemical phenomenon. When two dissimilar metals are metallically connected in an electrolyte, a current flows in the electrolyte from the corroding metal (the anode) to the more "noble" metal (the cathode) which does not corrode. Cathodic protection is a means of making the corroding metal a cathode. Two methods of providing cathodic protection are in use. These are the sacrificial anode method and the impressed voltage method. The sacrificial anode method involves using less "noble" metals as anodes in electrical contact with the metal to be protected. The less "noble" metal then corrodes instead. Zinc, magnesium, or aluminum are usually used as the sacrificial anode. Note that if this procedure is used to protect the interior of water tanks, corrosion products of the sacrificial anode could enter the water. In the impressed voltage method, an electric current is provided by an external source and is passed through the system by use of a non-corroding anode, such as carbon or platinum, which is suspended in the water.

Cathodic protection is frequently used in conjunction with a protective coating to control corrosion. The coating acts as an

Table 3-1

COMPARISON OF ALTERNATIVE WATER SYSTEM LININGS WITH RESPECT TO SELECTED VARIABLES AFFECTING THEIR USE

Coating	Use	Surface Preparation	Number of Coats	Total mil Thickness	Curing Time	Environmental Restrictions during application & drying.	Comments
Coal Tar hot applied enamel cold applied paint	 Tanks & Pipes Tanks	Commercial blast	 2-3 2-3	 62-124 16-20	 5-10 days 5-10 days	 >10°C >4°C	1) shortage of qualified applicators 2) hot applied-predominantly west coast use 3) skin and eye irritant
Coal Tar Epoxy	Tanks & Pipes	Near-white blast	2	16	5-10 days depending on temperature	>10°C	1) short pot life 2) shortage of refined pitch 3) solvents which must be used don't comply with Rule 66, California Pollution Laws 4) may contribute to taste & odor problems
Vinyl	Tanks	Near-white blast	3-5	4.5-6.0	2 days with heated air 5-14 days @ 21°C	2-32°C <80% R.H.	1) at least 24 hours drying between coats for solvent release is recommended
Epoxy	Tanks & Pipes	Near-white blast	2-3	8.0-15	7-10 days @ 16°C temperature must be greater than 16°C for curing	>10°C <80% R.H.	1) Ameron recommends baking at 60°C for 24-48 hours for proper curing 2) at least 24 hours drying time between coats but not longer than one week 3) skin irritant
Chlorinated Rubber	Tanks	Near-white blast	3	6.0-9.5	7 days	Not critical	1) not widely used for water storage tanks
Metallized Zinc	Tanks	White metal blast	1	7.5-10.0	none	No restrictions	1) metal must be applied immediately after blasting 2) toxic fumes produced
Wax cold applied hot applied	 Tanks Tanks	Removal of loose particles only	 1 1	 20-30 30-60	 24 hours 24 hours	>4°C unless heated	1) wax coatings are predominantly used to recoat old tanks 2) tanks are usually only out of service 2-5 days (100,00 gal tank)
Phenolic	Tanks	Commercial blast	3	3-5	7 days	>4°C	1) intercoat adhesion problems
Zinc-rich	Tanks	Near-white blast	1	2-5	7 days	>2°C R.H. 50-85%	1) used predominantly as primer
Asphalt	Tanks	Commercial blast	3	15	7 days	>4°C	1) major use is for recoating (maintenance)
Cement-mortar	Pipes	Removal of loose or foreign matter	1	250-500	7 days	Above freezing	1) Limits allowable pipe deflection 2) Has self-healing characteristics for small cracks 3) Seal coat is used over mortar in cast iron pipe 4) Subject to decalcification in soft water if seal coat not used

insulator and minimizes the current requirements of cathodic protection. The cathodic protection system protects areas which may have lost the protection of the coating due to coating discontinuity or coating failure. Cathodic protection has been used to protect the interior of water tanks and the exterior of buried water pipes. It cannot be used to protect the interior of pipelines (Koppers, 1978).

Water Conditioning - Water treatment and conditioning can also be used to control corrosion. The presence of oxygen is required for corrosion of iron and steel to take place. If oxygen can be removed from the water, corrosion will not occur. However, removal of oxygen from the large volumes of water involved in potable water supply systems is usually not practical. Calcium carbonate films formed by precipitation of calcium carbonate onto the metal surface will also retard corrosion (Merrill and Sands, 1978).

Non-corroding construction materials - Water pipelines and storage tanks can also be constructed of materials that are less susceptible to corrosion than iron and steel. Pipes and tanks can be fabricated from polyvinyl chloride, fiberglass-reinforced plastic, asbestos cement, stainless steel, concrete, copper, wood, polyethylene, and other materials. Limitations on the use of these alternatives include cost and ability to withstand environmental stresses. Iron and steel are generally the cheapest metals available. They are also strong and capable of withstanding the environmental stresses to which water pipes and storage tanks may be subject. These include,

for example, wind, earthquake, and, in the case of buried pipe, the effect of heavy traffic and the pressures developed underground during winter freeze-thaw cycles.

In terms of miles of pipe in place in the U.S., cast iron is the leading type of water pipe. It accounted for more than 75 percent of water pipe mileage in place in 1975. It also accounted for 45.8 percent of the water pipe mileage installed in 1975. Asbestos cement pipe and steel pipe account for 13.1 and 5.9 percent, respectively, of water pipe in place in 1975. The use of steel pipe for new installations showed a decline in 1975 when it accounted for only 3.4 percent of water pipe mileage installed. A summary of pipes installed in 1975 and pipe in place in 1975 by type and size of pipe is presented in Table 3-2.

Water storage tanks have been constructed of wood, fiberglass and concrete. Concrete has been widely used for the construction of large capacity tanks. It is estimated that almost 15 percent of new water tanks are constructed of concrete. Concrete is considered economical for tanks with capacities between 1.25 and 5 million gallons. Below that, steel is more economical (Meek, 1978). Steel is also more adaptable for elevated use (Koppers, 1978). A concrete tank has lower maintenance costs than a steel tank because it does not require a protective coating (Dickson, 1978). In the Northwest region of the country, leakage problems have been encountered with concrete tanks and their use has been discontinued in that area (Baker, 1978).

TABLE 3-2

PIPE USED IN U.S. WATER SUPPLY DISTRIBUTION SYSTEMS BY UTILITIES SERVING OVER 2,500 PERSONS

TYPE OF PIPE	MILEAGE IN PLACE (beginning of 1975)	% OF TOTAL	MILEAGE INSTALLED (1975)	PERCENT OF PIPE MILEAGE IN PLACE AT BEGINNING OF 1975 BY DIAMETER			
				Under 6"	6"-12"	13"-24"	Over 24"
Cast Iron	481,816	75.29	6,847	15.7	76.7	6.6	1.0
Asbestos Cement	83,871	13.11	3,743	9.7	86.3	4.0	0.1
Steel	37,852	5.91	505	53.4	29.5	10.7	6.4
Reinforced Concrete	10,083	1.58	517	0.2	4.1	43.4	52.3
Plastic	6,981	1.09	1,826	62.0	37.3	0.6	0.1
Ductile Iron	7,498	1.17	1,388	*	*	*	*
Galvanized Wrought Iron	2,364	0.37	3	*	*	*	*
Wood	1,246	0.19	*	*	*	*	*
RCP Steel Cylinder	652	0.10	8	*	*	*	*
Black Galvanized Iron	431	0.07	*	*	*	*	*
Copper	312	0.05	*	*	*	*	*
All others and unidentified	6,879	1.07	96				

Source: Scott and Caesar, 1975

*Not Specified

Approximately 100 redwood tanks are used by the California Water Service. A typical tank has a capacity of 25,000 to 50,000 gallons, the largest being 250,000 gallons. Because of their limited capacity, wood tanks are no longer being constructed for the California Water Service. The Service is attempting to salvage some leaky tanks by lining them with fiberglass-reinforced plastic. The wood is used as a frame for construction. The result is a fiberglass-reinforced plastic tank supported by the wood.

Some fiberglass-reinforced plastic tanks are in use for potable water storage but they are not common (Meadows, 1978). Cost and quality control problems with onsite fabrication of large fiberglass-reinforced plastic tanks generally limit the capacity of the tanks to that which can be shop fabricated and transported (Reinhart, 1975). Fiberglass tanks of up to 48,000 gallon capacity have been shop constructed (Kraft, 1978).

Comparative cost information for tanks of concrete, fiberglass-reinforced plastic, wood and steel is presented in Table 3-3.

3.1 Water Supply Industry Preferences for Protective Linings in the Water Distribution System

The selection of materials to be used in a water distribution system is influenced by many factors. The foremost consideration in the selection of material that will be in contact with potable water is its potential to introduce toxic substances or taste and odor into the water. For information on the acceptability of materials in this regard, water supply utilities and contractors rely on the advice of

TABLE 3-3

COMPARISON OF THE COST OF CONSTRUCTION OF WATER TANKS BY CONSTRUCTION MATERIAL

TANK CAPACITY (gallons)	CONSTRUCTION MATERIAL					
	WOOD	FIBERGLASS-REINFORCED PLASTIC	CONCRETE	STEEL		
	GROUND LEVEL	GROUND LEVEL	GROUND LEVEL	GROUND LEVEL	STANDPIPE	ELEVATED
3,000	3,780	--	--	--	--	--
10,000	8,140	--	--	--	--	--
20,000	10,485	--	--	--	--	--
30,000	13,185	--	--	--	--	--
45,000	16,615	22,500	--	--	--	--
50,000	--	--	--	--	--	105,000
100,000	--	--	--	35,000	--	130,000
250,000	--	--	92,000	52,000	--	195,000
500,000	--	--	132,000	77,500	125,000	280,000
1,000,000	--	--	212,000	145,000	192,500	490,000
2,000,000	--	--	333,500	240,000	325,000	--
4,000,000	--	--	546,000	420,000	--	--
6,000,000	--	--	760,000	600,000	--	--
8,000,000	--	--	--	760,000	--	--
10,000,000	--	--	--	900,000	--	--

Sources: Means, 1975 for all except fiberglass reinforced plastic tanks.
Kraft, 1978 for fiberglass reinforced plastic tanks.

*-- means cost data not available from above sources.

state and local health departments, and various U.S. government agencies, including the U.S. Public Health Service, the Food and Drug Administration and the U.S. Environmental Protection Agency. Acceptability is based on a determination that the coatings contain no toxic ingredients and on the results of an extraction test. The extraction test measures the weight of extractables in a water sample exposed to the cured coating (see Appendix E).

The other important factors influencing selection are the durability and cost of the material. In choosing from among several acceptable alternatives, the experience and preferences of the contractor or public works engineer regarding the various alternatives will influence the choice.

Until recently, the most widely used lining materials for steel water pipe were hot applied coal tar enamel and cement mortar. Epoxy linings are now beginning to be used. Three pipeline companies indicated that they only use epoxy to line steel pipe (Kipin, 1978; Lingle, 1978; Husselbaugh, 1978). The AWWA has issued a standard for coal tar epoxy lining for steel water pipe (AWWA, 1978). One of the reasons given for switching from coal tar enamel is the difficulty of controlling fumes released during application of the enamel (Lingle, 1978; Kipin, 1978; Husselbaugh, 1978; Roschburg, 1978). One pipe lining company indicated that they use coal tar enamel for 60 percent of their pipe lining jobs and epoxy for another 25 percent of their jobs. It was stated that coal tar is 75 to 80 percent cheaper than

epoxy on large jobs. However, water supply industry pipe lining jobs could not be separated from other pipe lining jobs (Crane, 1978).

Over 1,000 steel water storage tanks are constructed each year (Harper, 1977; Hauser, 1977; Lawrence, 1977; Arnell, 1977). Many different linings have been used. Some localities prefer coal tar enamel. In Seattle, nearly 100 percent of the steel water tanks are lined with coal tar enamel. In 1977, in Seattle, 14 of 15 new water tanks were lined with coal tar enamel (Garrison, 1978). In Los Angeles, coal tar enamel is used above the low water mark (Lemans, 1978). Coal tar enamel is used to line water tanks in Atlanta; however, if relining is required, vinyl is used (Layton, 1978). Vinyls and epoxies are used in Houston, exclusively (Healer, 1978). Virginia has withdrawn coatings that contain lead, coal tar, vinyl, barytes, lampblack, carbon black, or bituminous material from their list of approved water tank linings (Bartsch, 1977). In Baltimore County, hot applied coal tar enamel was used to line steel water tanks in the past. However, new specifications call for a chlorinated rubber type paint. The major reason for abandoning coal tar is the difficulty of controlling fumes (Silham, 1977). The California Water Service has 175 coal tar enamel lined tanks in service. They recently stopped using coal tar enamel in new tanks because of reports that it may introduce toxic substances to the water. A new

proprietary bituminous coating system that is advertised as FDA certified* for contact with potable water is being tried (Steiber, 1978).

California has had poor experience with vinyl paints. It was reported that a high solids vinyl failed in less than a year in a California water tank (Dickson, 1978). Steiber (1978) stated that vinyl does not hold up well in soft water. Formulation changes required to meet California air pollution control regulations are also believed to adversely affect the performance of vinyl paints (Boyd, 1978). Epoxy paints are also adversely affected for the same reason.

There are no statistical data on the number of tanks lined with particular paints. Estimates of the extent of use of different paint systems nationwide were solicited from tank fabricators, coatings suppliers and engineers. The estimates are tabulated in Table 3-4. It can be seen that the estimates are conflicting. The reason for the conflicting responses is believed to be that the estimates reflect the personal experiences of the estimator and may also be influenced by personal preferences or interests. An engineering consultant estimates that his company specifies high solids vinyl for 90 percent of its projects and epoxy linings for the remaining 10 percent (Brotsky, 1977). Two of the larger water tank maintenance companies in the United States (Pittsburgh Tank and Tower Company and Leary Construction Company) estimate that 70 to 80 percent of all

*The FDA states that they do not certify coatings for use in potable water.

Table 3-4

TABULATION OF VARIOUS ESTIMATES OF THE PERCENTAGE OF NEW WATER TANKS LINED WITH A GIVEN PAINT SYSTEM NATIONWIDE

Paint System	Garrett 1977	Wallace 1977	Enoch 1977	Songer 1977	McCoy 1977	Fisher Tank	Van Sant 1978	Dickson 1978	Campbell 1978	Carvlin 1978
Vinyl	80-90	90	47.5	75	*	90	90	-	-	50
Epoxy	10-20	6	47.5	15	50*	9	10	-	-	14
Coal Tar	0	0	5	0	*	1	0	90	0	13
Other	-	4	0	10	-		0	-	-	17**

*Estimated as 50 percent vinyl and coal tar and 50 percent epoxy.

** Includes 8% asphalt

water tanks in the country are lined with wax. They currently coat about 700 to 800 tanks per year, but most of this is recoating of older tanks. Jackson (1970) states that wax coating has practically gone out of use.

3.2 Comparison of the Cost of Alternative Protective Linings

Many factors enter into the decision of choosing a particular protective lining for water tanks and pipelines. Among the important factors is the cost of the lining. In water distribution systems it is desirable to minimize maintenance requirements that would entail an interruption to service. Thus, the benefits of a durable lining may outweigh initial cost differences between linings. A better cost comparison is one based on the life cycle cost.

The cost of lining a pipe or a tank depends on many factors, including weather, season of the year, union restrictions, environmental regulations, the availability and cost of manpower and supplies, degree of surface preparation, methods of application, the type of painting system, and other factors. Many of these factors are job-specific and therefore cannot be considered in a general comparison of the costs. In order to present a reasonable cost comparison between linings for purposes of this paper, estimates were obtained from the published literature and from paint suppliers, engineering consultants, and painting contractors (Table 3-5). In addition, costs were calculated for selected linings using Means Cost Data, 1975 (Means, 1975) and the Estimating Guide of the Painting and

TABLE 3-5

ESTIMATES OF THE COST OF APPLYING SELECTED LININGS TO POTABLE WATER TANKS BY SOURCE

Coating	Source	Surface Preparation $/Sq ft	Materials $/Sq ft	Application $/Sq ft	Initial Cost $/Sq ft	Service Life Years	Cost Effectiveness $/Sq ft /year
3-coat vinyl	Brotsky, 1977	1.00	0.22				
	Koppers	0.50	0.11	0.50	1.11	8	0.139
	Means	1.00		0.16			
	Sterling Chemical	0.47	0.15	0.33	0.95	8	0.119
	AWWA, 1970						
4-coat vinyl	Koppers	0.50	0.15	0.50	1.15	8	0.144
	Means	1.00		0.21			
	Sterling Chemical	0.47	0.18	0.43	1.08	10	0.108
	AWWA, 1970	0.24	0.09	0.22	0.55		
1-component epoxy	Koppers	0.50	0.15	0.50	1.15	10	0.115
	Means	0.75	0.25	0.50	1.50		
	Sterling Chemical	0.47	0.08	0.31	0.86	10	0.086
	AWWA, 1970	0.24	0.06	0.17	0.47		
2-component epoxy	Brotsky	0.30	0.15				
	Koppers	0.50	0.15	0.50	1.15	10	0.115
	Means	0.75	0.50	0.70	1.95		
	Sterling Chemical	0.47	0.18	0.25	0.90	15	0.060
Coal tar epoxy	Brotsky	0.30	0.15				
	Koppers	0.30	0.15	0.30	0.75	10	0.075
	Means	0.75		0.25			
Coal Tar							
cold applied	Koppers	0.30	0.13	0.30	0.73	12	0.061
	Means	0.75	0.25	0.30	1.30		
	Robison-Burnap				0.85-1.25	15	0.055-0.083
hot applied	D. E. Burgess Co.	0.40	0.15	0.60	1.15		
	SKILL Painting	0.40	0.10	0.60	1.10		
	Robison-Burnap				1.50-2.00	20	0.075-0.100
Chlorinated Rubber	Brotsky	0.30					
	Koppers	0.50	0.14	0.50	1.14	6	0.190
	Means	0.75		0.16			
	Hargas, 1978	0.30	0.05	0.15	0.50		
Metallized Zinc	Warner	1.65	0.50	1.75	3.90	40-50	0.098-0.078
Wax	Pittsburgh Tank Co.				0.35	4	0.088
	Kessler Tank Co.	0.12	0.04	0.29	0.45	5	0.090
Zinc-rich	Brotsky	1.00					
	Means	1.00	0.25	0.15	1.40		
Phenolic	Brotsky	0.30	0.13				
	Koppers	0.50	0.11	0.50	1.11	6	0.185
	Means	0.75					
Asphalt							
Inertol #49 Thick[R]	Koppers	0.30	0.10	0.30	0.70	6	0.117
	Means	0.75		0.30			
Petropoxy[R]	Koppers	0.50	0.24	0.50	1.24	15	0.083
	Means	1.00		0.30			

Table 3-6

MITRE COST ESTIMATES
FOR APPLYING SELECTED LININGS TO POTABLE WATER TANKS

Coating	Surface Preparation $/Sq ft	Materials $/Sq ft *	Application $/sq ft	Initial Cost $/sq ft	Service Life Years **	Cost Effectiveness $ Sq ft/year	Relative Costs
Coal Tar Enamel (hot)	0.50	0.14(Lingle)	0.30	0.94	50	0.019	1.00
3-coat vinyl	0.80	0.15	0.16	1.11	23	0.048	2.53
Metallized Zinc	0.80	0.50(Warner)	1.15	2.45	50	0.049	2.58
4-coat vinyl	0.80	0.20	0.21	1.21	23	0.053	2.79
Chlorinated Rubber	0.50	0.17	0.16	0.83	15	0.055	2.89
Coal Tar paint (cold applied)	0.50	0.13	0.30	0.93	15	0.062	3.26
Coal Tar Epoxy	0.50	0.20	0.25	0.95	14	0.068	3.58
2-component epoxy	0.80	0.15	0.16	1.11	14	0.079	4.16
Asphalt Petropoxy[R]	0.80	0.24	0.30	1.34	15	0.089	4.68
Wax	0.12(Schetzer)	.04(Shetzer)	0.29(Schetzer)	0.45	5	0.090	4.74
1-component epoxy	0.80	0.12	0.16	1.08	10	0.108	5.68
Asphalt Inertol #49 Thick[R]	0.50	0.11	0.30	0.91	6	0.152	8.00
Phenolic	0.50	0.11	0.16	0.77	4	0.193	10.16
Zinc-rich	0.80	0.25(Means)	0.05	1.10	5	0.220	11.58

*Costs from Koppers unless otherwise indicated
** Service Life is an average of estimates obtained from vendors and users by phone.

Decorating Contractors of America (PDCA, 1977). These are tabulated in Table 3-6. In addition to the total cost, the tables include the three main cost components: surface preparation, materials, and application cost. An annualized cost based on the estimated service life of the lining is also presented. Table 3-6 includes a relative cost figure which is the ratio of the annualized cost of the lining and the annualized cost of a coal tar enamel lining.

The cost-effectiveness of a lining and thus its relative cost, is sensitive to its service life. For example, if a 3-coat vinyl lining lasts only 8 years instead of 23 years, its cost-effectiveness and relative cost would approximately triple. Unfortunately, the reported service life for each lining varies widely. A poor service life may have been experienced because of faulty application procedures rather than because of the inherent properties of the lining. Thus, the cost-effectiveness and the relative cost figures indicated in the table may not reflect achievable costs.

The most significant component of the initial cost of most linings is the cost of surface preparation. However, since surface preparation has a major influence on the service life of a lining, it is generally not advisable to try to "cut corners" in this area of the job.

There is also uncertainty regarding the cost of applying hot coal tar enamel. There is disagreement concerning the degree of skill required to apply the hot coal tar enamel. Some references

point out the importance of using experienced applicators (SSPC, 1973; Bureau of Reclamation, 1976). According to the SSPC, some consulting engineers demand that a contractor submit at least 10 5-year case histories in order to qualify. Other reports (Wood, 1975; Steiber, 1978) state that coal tar enamel is tolerant to poor surface preparation and to mistakes in application. It is reported that the number of experienced applicators is dwindling, particularly in the east, and that those who are willing to apply the coal tar demand upwards of $2.00 per square foot (Campbell, 1978). However, as can be seen in Tables 3-5 and 3-6, most cost estimates were about half that amount.

The choice of pipe material for water main construction is based upon technical considerations at the particular installation (soil conditions, potential for future connections, location), material availability, and cost, tempered by the personal preferences of the utility or contractor (Imhoffer, 1973). With regard to cost, asbestos cement pipe in sizes up to 3 inches is about half the cost of cement lined cast iron pipe (Means, 1975). Unlined steel pipe in sizes up to 8 inches is between 1-1/2 and 2-1/2 times the cost of cement mortar lined cast iron pipe (Means, 1975). Steel pipe is commonly lined with cement mortar, hot applied coal tar enamel or epoxy. Materials cost for enamel and cement mortar are approximately 14 cents and 34 cents per square foot, respectively (Lingle, 1978; Lawrence, 1977). However, surface preparation

requirements for application of the coal tar enamel are greater and more costly and tend to equalize the total cost for lining with that of cement mortar. The cost of lining steel pipes with epoxy was estimated at 60 cents per square foot (Kipin, 1978).

4.0 UTILIZATION OF COATING MATERIALS

In this section the methods for application of the various coating materials are delineated followed by a brief discussion of the expected and identified problems associated with application.

4.1 Application Methods

The performance of a protective coating depends in large part on surface preparation and on careful and proper application of the coating. Specification of the requirements necessary for a complete paint job have been published by the Steel Structures Painting Council (1973), the American Water Works Association (AWWA, 1972; AWWA, 1964), and by the coating manufacturers. It has been shown that a near-white blast cleaning or white metal blast cleaning is the minimum level of surface preparation required for long-term performance (Berger, 1976). The draft AWWA standard for painting and repainting steel tanks (AWWA, 1977) specifies a near white blast cleaning or pickling of the tank surface before application of most coating systems. Pickling removes all mill scale, rust and rust scale from the metal surface. Blast cleaning removes nearly all mill scale rust, and rust scale, and can also remove paint and other foreign matter. White metal blast cleaning is essentially equivalent to pickling in the degree to which the metal surface is cleaned. A near-white blast cleaned surface is 95 percent free of all visible discoloration. A commercial blast cleaned surface is two-thirds free of all visible discoloration.

The first coat of paint should be applied as soon as possible after cleaning to prevent rust formation. If rust is allowed to form before the paint is applied, it is necessary to clean the metal again.

Protection of the steel surface depends on good bonding of the paint to the steel and to prior coats, and on film thickness. Proper curing procedures also must be followed. If a coating dries too slowly, excessive dust and dirt may accumulate on the coating. There may be a maximum time interval between application of successive coats to assure good intercoat adhesion. Poor ventilation can retard curing of the coating by slowing evaporation of the solvent. Since solvent fumes are heavier than air they will collect at the bottom of the tank unless steps are taken to remove them.

Pipe linings can be applied in the shop or the field. Storage tanks, because of their large size, are usually erected in the field and lined in place.

Hot coal tar enamel and cement mortar linings are usually shop applied to pipes by a centrifugal lining process. The process involves feeding the lining material into the bore of a rotating pipe so that the lining material is spread uniformly over the pipe bore by centrifugal force. Fittings are lined by manual methods.

Coal tar enamel linings can be damaged at joints if pipe sections are connected by welding. In pipes larger than about 27 inches in

diameter, the joints can be manually lined in the field, otherwise mechanical joining methods are used.

Cement mortar can also be applied to pipe interiors by a spray process. In this process, a centrifugal applicator head, situated at the end of a lance that is supported on a wheeled carriage, is pushed through the pipe. The mortar mix is pumped through the lance to the applicator head which throws the mix onto the pipe surface.

Epoxy linings are usually field applied after the pipe is in place and all welding is complete. The lining can be applied by forcing the epoxy mixture through calibrated orifice openings in pigs in the correct quantity against the pipewall as the pig is propelled through the pipe by compressed air. If the lining is shop applied, mechanical pipe joining methods are used.

Hot applied coal tar is applied to storage tanks by a hand daubing procedure. Other linings are usually spray applied to a specified film thickness in one or more coats.

A summary of the application procedures for several pipe and tank linings are included in Appendix D. The manufacturers recommendations should be followed with regard to the time to allow for curing of the paint before placing the tank or pipe in service.

Following application and curing of the lining, the water tank or pipeline is disinfected before it is placed in service. Some state and local health departments have developed their own procedures. The AWWA has described two acceptable methods for disinfecting water tanks in their standard for painting water tanks (AWWA, 1964).

The first AWWA method calls for filling the tank slowly to the overflow level with potable water to which enough chlorine has been added to produce a concentration of 50 ppm in the full tank. Filling the tank will provide a thorough mix of the chlorine and water to assure contact with all surfaces for disinfection. After the tank has been filled it must stand full for about 6 hours, preferably 24 hours. After this holding period, the tank is drained and then refilled using the regular water supply. Water samples must be taken to determine the effectiveness of the disinfection process.

Use of the second method is less desirable (Trichilo, 1979). It calls for placing water containing 50 ppm chlorine in the tank to a level which will enable a concentration of 2 ppm to be attained when a sufficient amount of regular water is added to fill the tank. The water containing 50 ppm of chlorine is held in the tank for 24 hours before the tank is filled with the regular water supply. The full tank is then allowed to stand for 24 hours. After this time, the tank may be put into service without draining the water used to disinfect it.

4.2 Problems Associated with the Application of Coatings

The problems associated with the application of coatings include:

- potential toxic effects of the paint on the applicator;
- requirements for control of emissions to the atmosphere;
- requirements for ventilation during application and curing;

- insuring adequate curing time before placing in service;
- safety in rigging; and
- visibility in the closed tank.

The latter two problems are common to the application of all coatings inside water storage tanks. The other problems vary according to the coating system used.

Ventilation is the key to safety for most paint systems since toxic and flammable solvents are components of most paint systems used. Sufficient ventilation must be provided to keep the solvent concentration in all parts of the tank below the lower explosive limit during the entire application and curing period. Since the solvent vapors may be heavier than air and settle to lower parts of the tank, they should be removed by suction ventilation. The blower size required to reduce vapor concentration in specific sized tanks is provided in Table 4-1. Occupational Safety and Health Administration (OSHA) regulations require solvent vapor concentrations to be below a specified level. Since this cannot be achieved by means of ventilation, air-supplied respirators must be worn by workers at all times.

In addition to ventilation requirements, spark-proof and explosion-proof equipment should be used. Smoking, matches, flames or sparks of any kind should be prohibited. These precautions represent the minimum steps to be taken to ensure worker safety. Special considerations need to be made for specific paint systems.

Table 4-1

BLOWER CAPACITIES REQUIRED TO MAINTAIN VAPOR CONCENTRATION WELL BELOW LOWER EXPLOSIVE LIMIT

Volume of Tank (Gallons)	Required Blower Size* (CFM)
500-5,000	1,000
5,000-20,000	2,000
20,000-100,000	5,000
100,000-250,000	10,000
500,000	15,000
1,000,000-2,000,000	20,000

*Suction type

Source: Ameron Company

Ventilation is also important for promoting evaporation of solvent from the paint film, thereby aiding the curing process. Improperly cured coatings may retain solvent residues that can subsequently enter the water and introduce taste, odor, or toxicity to the water supply (Wellington, 1971).

In addition to the hazards associated with the solvents, the film forming ingredients of the paint may also present a hazard to the applicator. There are several hazards associated with the use of coal tar based coatings. The National Institute for Occupational Safety and Health (NIOSH) has published a criteria document on the effects of exposure to coal tar (NIOSH, 1977). Exposure has been reported to produce phototoxic effects such as skin erythema, burning and itching, photophobia and conjunctivitis. In addition, exposure can increase the risk of lung and skin cancer. NIOSH recommends an exposure limit of 0.1 mg/m^3 of the cyclohexane-extractable fraction of the sample. This is of particular concern during application of the hot applied coal tar enamel because volatile constituents of the coal tar are released at the temperature of application.

The strongly alkaline amine type catalysts used in epoxies are irritating to some people (Berger, 1976). The vinyl paints may contain free vinyl chloride, a known carcinogen. Urethane coatings contain free toluene diisocyanate or isocyante monomer which will cause severe skin irritation (Berger, 1976).

A hazard also exists in the use of metallic zinc coatings. Exposure to the zinc oxide fumes can produce metal-fume fever.

This condition is not fatal but causes severe discomfort which lasts a day. The American Conference of Governmental Industrial Hygienists and the Occupational Safety and Health Administration established a zinc oxide fume concentration exposure limit of 5 mg/m^3 for workers. To ensure workers' safety, air-supplied respirators must be worn during the metallizing procedure.

Wax seems to be the least hazardous of available coatings to apply. The formulation commonly used contains petroleum solvents such as kerosene. No special protective equipment is used during application.

Application of the coatings may also contribute to air pollution. Solvents used in the coatings are often photochemically reactive and contribute to the photochemical smog problem. In California, where there is a serious pollution problem, substitution of non-photochemically reactive solvents has sometimes adversely affected paint performance (Boyd, 1973). Visible emissions and odors emanating during the shop application of hot applied enamel to pipes has resulted in the abandonment of the use of hot applied enamel for this purpose in some locations (Lingle, 1978; Kipin, 1978).

5.0 TOXICOLOGICAL CONSIDERATIONS OF THE MATERIALS USED AS LININGS

Factors affecting the health risks to the general public associated with a particular material used for lining pipes or tanks that are part of a potable water distribution system include the following:

- those compounds contaminating the water as a result of contact with the lining material,
- the rates with which these compounds leach into the water, including constancy of the leaching process over time,
- the water solubilities of those compounds that do leach,
- the effect of chlorination, ozonation, pH, dissolved solids, etc., on the potential for leaching and on leaching rates,
- the concentrations in the water of those compounds that do leach (both in the system and at the tap),
- the rates of decomposition and the decomposition products of the detected compounds,
- the reactions of leached compounds with compounds already present in the water (e.g., resulting from disinfectant techniques),
- the characteristic synergistic, antagonistic, and additive interactions of the compounds present,
- the potential for adverse health effects due to ingestion and metabolism of the compounds,
- the relative risk of exposure to these compounds in water (i.e., compared with contributions to the body burden from other exposure sources), and
- the relative risk presented by utilization of the lining material being investigated versus that inherent to alternative lining materials.

In the sections that follow, the currently available data items that describe many of these factors are presented.

5.1 Compounds Identified in Potable Water and Attributed to the Use of Lining Materials

Data are available from one investigation, which identified numerous compounds in potable water and attributed their presence to the utilization of a coal tar pitch coating in a ground storage water tank (McClanahan, 1978). Sampling of the water in the 750,000 gallon Bayou Casotte tank in Pascagoula, Mississippi, was precipitated by repeated taste and odor complaints after the coating, Bitumastic Super Tank Solution (manufactured by Koppers Company, Inc.), had been applied. Although the coating was dried and the tank was disinfected and refilled four times, there were taste and odor complaints and/or unacceptable bacteria counts after the first three times (Compton, 1978). Eighteen compounds were identified in the first samples, obtained approximately 5 months after the coating was applied (Table 5-1). The water from which these samples were obtained had a contact time* of 6 days, while the estimated retention time* was 6.1 days. The second sampling occurred approximately 3.5 months after the first and revealed the presence of 12 compounds. Samples were acquired from the top of the tank, as for the first sampling; however, the sample

*Contact time is the maximum period of time that the water could have been in contact with the tank (i.e., time elapsed from the beginning of flow into the tank for refilling purposes until the sample was obtained), while retention time is the estimate of actual residence time for the water in the tank (i.e., rate of turnover as calculated by dividing the volume of the tank by the rate of discharge from the overflow valve). Retention time is normally the measurement of choice, but in this case contact time was calculated because only one measurement of the rate of discharge from the overflow valve was made. As this rate can fluctuate dramatically from day to day, it was felt that, for accuracy, contact time would be more appropriate.

TABLE 5-1

ESTIMATED CONCENTRATIONS OF COMPOUNDS DETECTED IN THE WATER IN THE BAYOU CASSOTTE GROUND STORAGE WATER TANK USING GAS CHROMATOGRAPHY/MASS SPECTROMETRY

Compound	Sample Date and Concentration (μg/l)				
	9/6/77		1/16/78	2/21/78	
	A	B	A	A	B
naphthalene	5.4	6.7		1.3	2.7
methyl naphthalene	0.75	1.4	0.63	<1	1.3
biphenyl	0.21	0.40		<1	<1
acenaphthene	2.8	4.6	1.3	3.1	8.0
dibenzofuran	3.1	5.0	1.1	2.3	6.3
fluorene	3.4	5.1	1.5	2.9	8.0
phenanthrene/anthracene	8.7	9.3	4.5	14	35
carbazole	0.70	1.3	0.44	3.9	11
bromoform	<10	<10	<10		
C_4 alkylchlorobenzene	<50	<50	<50	2.7	7.3
indene	<10	<10			
C_3 alkylbenzene	<10	<10			
anthraquinone	<10	<10	<10	2.3	8.3
methyl benzofuran	<10	<10		<1	1.0
quinoline	<10	<10		<1	<1
methyl styrene/indan/indene	<10	<10		1.7	2.6
methylene phenanthrene/methyl phenathrene	<10	<10	<10	1.2	4.0
pyrene	<10	<10	<10	2.2	7.0
2,5-diethyltetrahydrofuran			11		
dimethyl naphthalene				1.2	2.7
fluoranthene				2.7	9.7

A Sample obtained from a valve approximately 3 feet above the bottom of the tank

B Sample obtained from the top of the tank

Source: Adapted from McClanahan, 1978.

from the top of the tank was lost before analysis. Contact and retention times for this sample were 2.8 and 58 days, respectively. Analysis of the third sampling, performed without draining the water from the tank after the second sampling, indicated the presence of 17 compounds. For these samples contact and retention times were 39 and 58 days, respectively. At the time the third pair of samples was obtained, samples of the raw water were taken prior to entry of the water into the tank. None of the compounds detected in any of the samples acquired from within the tank were present in the raw water samples.

It was suggested that the relatively high concentrations detected in the 2/21/78 sample obtained from the top of the tank may have resulted from the action of convection currents in the water. Prior to this sampling, the flow of water through the tank had ceased for 4 days. During this time solar heat would have been transferred from the walls of the tank to that water immediately adjacent to the walls, thereby increasing its temperature. This water, which under the conditions of no forced flow would contain the highest concentrations of any materials leaching from the coating, would tend to rise to the top of the tank. As a result, it might be expected that the leached compounds would be present in higher concentrations toward the top of the tank.*

*N.B. Flow was resumed 1 hour prior to sampling. This flow was not, however, considered sufficient to have completely disturbed the elevated concentrations at the top of the tank before the samples were obtained.

In a study in Portland, Oregon, water samples were obtained from the source and the terminal point of a coal tar (type unspecified) lined pipe, 24 inches in diameter and 2.43 miles in length (Robeck, 1978). Table 5-2 indicates the compounds and the concentrations detected at both the source and at the end of the pipe. This was the only other report available of compounds detected in drinking water that were attributed to leaching from coal tar based lining materials.

The data cited do provide evidence for leaching from the coal tar linings into the water, and some compounds have been identified. However, there are no indications of leaching rates, the fluctuations of those rates, the effects of water quality on leaching rates, the solubilities of the leached compounds, the extent and products of decomposition of the leached compounds, the ultimate concentrations to which the general public might be exposed via drinking water, the interactions between the compounds both before and after human exposure, or the potential for adverse effects on human health.

Table 5-3 lists the compounds identified in the Bayou Cassotte ground storage water tank and indicates those for which atmospheric detection has been reported. Data concerning quantification of these compounds in the air are, at best, limited. Table 5-4 lists those compounds, detected in the Bayou Cassotte ground storage water tank, for which actual atmospheric concentrations have been found.

No data revealing total dietary intake of the compounds detected in the Bayou Cassotte ground storage water tank were found. There

TABLE 5-2

COMPOUNDS DETECTED IN THE WATER SAMPLES OBTAINED IN PORTLAND, OREGON

Compound	Concentration (ng/l) A	B
phenanthrene	∿3	3225
1-methyl phenanthrene	-	NQ
2-methyl phenanthrene	-	NQ
fluoranthene	<1	572
pyrene	<1	671
chrysene	-	32
benzo(b)fluoranthene	<1	4
fluorene	-	NQ
acenaphthene/biphenyl	-	NQ

A At the source

B At the end of 2.43 miles of coal tar lined pipe

NQ Not quantifiable

Source: Robeck, 1978.

TABLE 5-3

ALTERNATE SOURCES OF THOSE COMPOUNDS IDENTIFIED IN THE BAYOU CASSOTTE GROUND STORAGE WATER TANK

COMPOUND	SOURCES					
	A	B	C_1	C_2	C_3	C_4
naphthalene		✓	✓	✓		
methyl naphthalene		✓	✓	✓		
biphenyl						
acenaphthene		✓	✓	✓		
dibenzofuran			✓			
fluorene		✓	✓	✓		
phenanthrene/anthracene	✓	✓	✓	✓		
carbazole		✓	✓			
bromoform						
C_4 alkylchlorobenzene						
indene						
C_3 alkylbenzene						
anthraquinone						
methyl benzofuran						
quinoline						
methyl strene/indan/indene						
methylene phenanthrene/methyl phenathrene						
pyrene	✓	✓	✓	✓	✓	✓
2,5-diethyltetrahydrofuran						
dimethyl naphthalene						
fluoranthene	✓	✓				

A Compound is a component of the particulate polycyclic organic matter (PPOM) emitted by coal-fired residential furnaces, which are the largest source of PPOM emissions from heat generation. The compound is also emitted through incineration, open burning, and motor vehicle exhaust.

B Among PPOM identified in 1961 by Sawicki and co-workers as being present in air or emitted to the air.

C Reported by Sawicki and co-workers and/or Hartwell and Shubik as being present in air (C_1), tobacco smoke (C_2), gasoline exhaust (C_3), or diesel exhaust (C_4).

Source: National Environmental Research Center, 1975.

TABLE 5-4

ATMOSPHERIC CONCENTRATIONS (DETECTED IN THE U.S.) REPORTED FOR THOSE COMPOUNDS IDENTIFIED IN THE BAYOU CASSOTTE GROUND STORAGE WATER TANK

COMPOUND	CONCENTRATION (ng/m^3)
methyl naphthalene	134 - 3,100,000
acenaphthene	0.0 - 2.5
pyrene	0.1 - 36 5.1 (average)
fluoranthene	5.5 (average)

Source: National Environmental Research Center, 1975.

were data available concerning the concentrations of three of the compounds (i.e., phenanthrene, fluoranthene and pyrene) in certain foodstuffs, largely smoked meat and fish (Santodonato et al., 1979). The concentrations of phenanthrene, fluoranthene, and pyrene found in coconut oil were 51, 18, and 15 ppb, respectively; while the range (in ppb) detected for each in smoked fish was 4.1 to 52, 1.8 to 12, and < 0.5 to 4.4. All these were also detected in smoked meats/meat products, and the concentrations (ppb) were: detected to 104 for phenanthrene, 0.6 to 49 for fluoranthene, and 0.5 to 42 for pyrene.

As is apparent, there is a minimum of data available indicating atmospheric and total dietary concentrations of these compounds.

The only other data available concerning leachates in potable water systems from materials used in the system are indicated below. In a determination of the potential for migration of vinyl chloride into water from polyvinyl chloride pipe, Dressman and McFarren (1978) detected low concentrations of vinyl chloride in four of five water distribution systems sampled. The five sampling sites were selected because they were representative of climatic extremes, and because data concerning age, length, and size of the pipes were available. Although only one sample was sufficiently high to be verified by mass spectrometry, the concentration as determined by gas chromatography ranged from 0.03 to 1.4 g/l. The data were limited but water in the newest, longest system had the highest concentration of vinyl chloride, while water from two 9-year-old systems had the lowest concentrations.

5.2 Amelioration of Potential Toxicological Problems

In the introduction to this chapter, a list was presented indicating those broad categories of data that would be essential for a thorough evaluation of the hazards presented by water contaminants derived from materials on distribution system contact surfaces. The first item (i.e., identification of those compounds contaminating the water as a result of contact with a lining material) is the only one that is addressed even minimally by the available data.

Currently, there are a limited number of evaluations that are being conducted by government or private laboratories that are applicable to the problem being reviewed. The tests being performed are essentially qualitative and quantitative leaching determinations. Table 5-5 indicates the laboratories performing the analyses and the material(s) being analyzed. Unfortunately, data generated by these studies were not available at the time this report was prepared.

TABLE 5-5

QUALITATIVE AND QUANTITATIVE LEACHING EVALUATIONS CURRENTLY IN PROGRESS

MATERIAL(S) BEING EVALUATED	EVALUATING LABORATORY
Coal Tar Epoxy Paint	Corps of Engineers Laboratory Champaign, Illinois[1]
Organic Coatings	National Association of Corrosion Engineers Katy, Texas[2]
Asphalt Seal Coat	Southern Research Institute Birmingham, Alabama[3]
Coal Tar Pipe Lining	Municipal Environmental Research Laboratory (EPA) Cincinnati, Ohio
Asbestos Cement Pipe	Municipal Environmental Research Laboratory (EPA) Cincinnati, Ohio
Plastic Pipe	Municipal Environmental Research Laboratory (EPA) Cincinnati, Ohio

[1] Olson, 1977.
[2] Dillard, 1978.
[3] Barrett, 1977.

6.0 CONCLUSIONS AND RECOMMENDATIONS

The water supply industry represents a relatively small portion of the total market for coal tar based coatings. One of the two suppliers of hot applied coat tar enamel stated that the water supply market accounted for approximately 10 percent of the company's sales of the enamel. The total value of coal tar products supplied to the water supply industry is estimated at two million dollars annually.

On the basis of the information obtained from industry representatives and presented in this report, it is concluded that there is a trend away from the use of hot applied coal tar enamel by the water supply industry. Reasons for this include:

- difficulty in finding experienced applicators,
- difficulty in complying with OSHA and EPA regulations regarding control of fumes during application,
- the availability of alternative linings, and
- increased awareness of a potential for leaching of toxic components of coatings into the water supply.

The use of a coal tar based epoxy paint for lining steel water pipes may increase because of a recently issued standard on coal tar epoxy for this use by the American Water Works Association. However, non-coal tar based epoxy is also used to line steel water pipes.

Although alternatives to coal tar based coatings are available and widely used, as with the coal tar based coatings, the potential for introduction of toxic substances into the water supply has not been adequately determined. The extraction tests that are currently

utilized to evaluate the acceptability of coatings for use on potable water supply contact surfaces are inadequate. They assess total leachates only; they do not provide a qualitative or quantitative indication of the extent of leaching from coatings.

Several research programs are currently underway which may provide data on the leaching characteristics of selected coal tar based linings and other materials that may be used for potable water distribution system contact surfaces; however, the results of these programs are not yet available.

In order to be able to identify those materials suitable for use as potable water contact surfaces and to provide guidance to utilities in upgrading existing systems or installing new ones, the following should be addressed:

- Develop protocols for determining the extent of leaching from the various materials applicable as coatings;
- Determine the qualitative and quantitative nature of the leachates under the expected conditions of use;
- Evaluate the individual and collective chemical reactivities of the leachates;
- Establish a monitoring system designed to determine the extent of leaching in water distribution systems currently being utilized; and
- Develop a toxicological data base tailored to facilitate comparisons of the various materials (i.e., estimations of relative risk).

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APPENDIX A

DESCRIPTION OF NONCOAL TAR BASED LINING SYSTEMS

Epoxy Paint Systems

Epoxy paints have been used on the interior surfaces of potable water tanks and pipelines with good results when properly formulated and applied. The resin for these coatings is proudced by the polymerization of epichlorohydrin and bisphenol A. As the proportionate amount of bisphenol A is increased, the resin becomes a hard, high molecular weight resin suitable for use in water immersion service. There are two types of epoxy coatings, the single component and the two-component.

A single component epoxy consists of an epoxy vehicle mixed with pigments. The vehicle consists of a high molecular weight epoxy resin reacted with a minimum amount of drying oil and modified with a reactive resin in suitable solvents. The resin dries by oxidation and polymerization.

This system adheres strongly to steel surfaces and exhibits satisfactory cohesion between the paint coats. In addition, it exhibits low permeability to water and oxygen. Technical data associated with a typical single component epoxy paint are included in Appendix B, Table B-10.

The two-component epoxy paints consist of a base and a hardener. The base contains the epoxy resin, pigments and solvent; the hardener is usually a polyamide or an amine plus a solvent. Phenolics have also been used as the curing agent or hardener.

The coating films of this system dry hard, with excellent adhesive qualities and low permeability to oxygen and water. Specifications for a typical two-component epoxy paint system are contained in Appendix B, Table B-11.

The draft AWWA standards for painting storage tanks (AWWA, 1977) specifies a two-component epoxy paint system. Two systems have been included. One is a three-coat system conforming to Military Specification MIL-P-24441 and the other is a two-coat system conforming to Military Specification MIL-C-4556.

Epoxy linings in pipelines have been shown to sustain high flow coefficients which enable smaller diameter pipes to be used for an equivalent flow capacity. Also, the thinner lining (0.008 inches as compared with 0.094 inches for coal tar and 0.30 inches for cement mortar) is an advantage for the epoxy, allowing increased flow capacity for a given diameter pipe (Cook, 1977).

Vinyl Paint

Vinyl paint resins are solutions of vinyl chloride-vinyl acetate copolymer and a hydroxyl compound such as vinyl alcohol and/or a carboxyl compound such as maleic acid. Vinyls are one of the most popular linings used in water tanks. In long-term immersion tests, all vinyl systems have shown outstanding performance when properly applied (Keane, 1975). Vinyls are inert in water, and provide a hard, tough, smooth film with low moisture absorption properties (Bureau of Reclamation, 1976).

The draft proposed AWWA standard for painting potable water storage tanks (AWWA, 1977) includes two interior vinyl paint systems. One is a five-coat vinyl system. The other is a four-coat system based on a high solids vinyl resin.

The five-coat system consists of a primer of basic zinc chromate vinyl butyral wash coat and four coats of a vinyl resin paint. Two of the vinyl resin coats are intermediate paint formulations and two coats are finish paint formulations. Three variations of the five-coat system are described in the draft proposed standard. The variations relate primarily to the composition of the finish coat and to the final film thickness.

The wash coat consists of two components which are mixed together prior to use. One component contains an alcohol solution of butyral resin pigmented with basic zinc chromate which acts as a corrosion inhibitor. The second component contains an alcohol solution of phosphoric acid which reacts with the vinyl resin, the pigment, and the steel. An approximate summary of the wash coat composition is presented in Appendix B, Table B-12. A typical composition of the vinyl resin paint used in this system is presented in Appendix B, Table B-13.

The four-coat system is a high solids vinyl formulation developed by the Bureau of Reclamation. It is called VR-3 paint (Bureau of Reclamation, 1967). Each coat uses the same paint; however, the thickness of each coat is different. The total dry film thickness is

0.005 inches. Three four-coat systems are described in the draft proposed standard. They differ only in the color of the finish coat. The vehicle of the vinyl paint used in this system is a solution of vinyl chloride-vinyl acetate-maleic acid tripolymer resin. The remainder of the resin is vinyl chloride-vinyl acetate copolymer or partially hydrolyzed copolymer. A plasticizer such as dioctyl phthalate is used. Solvents that may be used include methyl isobutyl keytone and toluene.

Wax Coatings

The AWWA standard for painting steel tanks (AWWA, 102-64) includes two wax coating systems that may be used inside water storage tanks. These are a hot applied wax and a cold applied wax system. Both are blends of petroleum waxes and oils containing proprietary active corrosion inhibitors. The characteristics of the coating are specified in Appendix B, Table B-14.

Chlorinated Rubber Coatings

Chlorinated rubber is made by exposing natural rubber to chlorine gas until it contains approximately 67 percent chlorine. The resultant resin is hard and brittle and must be plasticized with other resins or with linseed oil or alkyd resin. These plasticizers make the paint more flexible and adherent to steel but also less resistant to water.

The chlorinated rubber vehicle used contains 50 to 60 percent by weight of chlorinated rubber and the remainder is solid or liquid chlorinated paraffin. Older formulations contained chlorinated biphenyls or polyphenyls. These compounds are no longer allowed to be used.

High-build systemn are formulated to allow a 0.005 to 0.006 inch dry thickness using three coats. A typical composition of a high-build chlorinated rubber paint that may be used in water storage tanks is included in Appendix B, Table 15.

Metallic Sprayed Zinc

Metallic sprayed zinc is 99.9 percent pure zinc wire that has been melted, atomized in high pressure air, and blown onto the steel surface as a 0.010 inch thick coating. It provides long service life and freedom from rust contamination. Specialized application skills and equipment are required and the surface of the steel must be blast cleaned to white metal before application. These requirements make this coating relatively expensive (Bureau of Reclamation, 1976)

Miscellaneous Paint Systems

Included in this section are paint systems which have been reported to be suitable for use in potable water service but which have not received wide use for various reasons. Some of these systems are relatively new and may be used more extensively in the future. Others have not performed well and have been abandoned.

Asphalt Based Linings

Asphalt is a term used to describe a variety of dark resinous materials; some are natural and some are by-products of petroleum cracking or distillation. Standards for asphalt coatings and linings customarily specify petroleum asphalt (Seymour, 1959). However, Koppers Company supplies asphalt coatings containing the natural resin, gilsonite. Gilsonite has been listed by the FDA as acceptable for use as a food contact surface (CFR 21, 1977).

Asphalt and asphalt enamels show less resistance to water absorption than coal tar enamels and pitches. They exhibit a rapid increase in water absorption with time whereas the water absorption curve for coal tar enamel does not increase with time. The rising water absorption rates for asphalt indicate eventual failure (Fair, 1956). For this reason, asphalt coatings are not widely used as a protective lining for new steel water tanks or pipelines. The AWWA does not include asphalt coatings in their standards for lining water pipelines or storage tanks. Asphalt based coatings are used to recoat existing asphalt lined tanks (Wagner, 1978). They are also used as a seal coat over cement mortar linings in cast iron and ductile iron pipe. In this service the coating serves primarily as a seal to retain the moisture in the cement long enough to effect proper curing.

Phenolic Based Linings

A lead aluminum phenolic paint system and a zinc phenolic system were listed in the AWWA standard for painting tanks (AWWA, 1964).

These paints received a poor rating in an evaluation of coatings for water tank interiors (Keane, 1975). They are not included in the draft proposed revision to the AWWA standard for painting tanks because of a lack of wide use.

Zinc Rich Linings

Zinc rich paints are composed of an organic or inorganic vehicle with a high zinc dust content. In organic vehicles the zinc dust content ranges from 80 to 95 percent by weight of total nonvolatile content. Inorganic zinc rich vehicles contain upwards of 95 percent by weight of zinc dust. The paints are formulated to provide hard, tough, abrasion resistant protection to steel. Rust inhibition is also provided due to the galvanic protection provided by the zinc. The zinc rich paints normally require a near-white metal blast cleaned surface and are applied in one coat to a 0.002 to 0.005 inch dry film thickness over the cleaned steel. Often they are used as primers and top coated with another paint. The zinc coating requires a 7-day drying period (SSPC, 1973).

In a water tank test, zinc dust-zinc oxide paints, in both phenolic and polyamide epoxy vehicles, were in good condition after 7 years (Keane, 1969).

Powder Linings

Epoxy powder coatings are also beginning to be used for lining pipelines. The powder is sprayed onto a heated pipe surface. The

hot pipe melts the powder which then forms a film which is fused onto the pipe. A major advantage of the powder coatings is the elimination of solvents which have been found to create occupational health hazards and air pollution problems (Lingle, 1978).

APPENDIX B

TYPICAL COATING CHARACTERISTICS

NOTE: The typical coating characteristics included herein are not sufficient by themselves to be used to specify a coating system. They are, however, an important part of the complete specification.

Table B - 1

Characteristics of AWWA Coal Tar-Enamel

Test	Enamel Type I		Enamel Type II	
	Minimum	Maximum	Minimum	Maximum
Softening Point, ASTM D36	220F	240F	220F	240F
Filler (ash), ASTM D271	25%	35%	25%	35%
Fineness filler, through 200 mesh, ASTM D546	90%	-	90%	-
Specific Gravity at 25C, ASTM D71	1.4	1.6	1.4	1.6
*Penetration, ASTM D5				
at 77F 100-g weight 5 sec	5	10	10	20
at 115F 50-g weight 5 sec	12	30	15	55
High temperature test at 160F (sag), AWWA C203, Sec. 2.8.8	-	2/32 in.	-	2/32 in.
Low-temperature test at -10F (cracking) AWWA C203, Sec. 2.8.9	-	None	N/A	N/A
Low-temperature test at -20F (cracking) AWWA C203, SEC.2.8.9	N/A	N/A	-	None
**Deflection test (initial heating), AWWA C203, Sec. 2.8.10				
Initial crack	0.5 in.	-	0.8 in.	-
Disbonded area	-	5 sq. in.	-	3 sq. in.
**Deflection test (after 2-hr heating), AWWA C203, SEC. 2.8.11				
Initial Crack	0.3 in.	-	0.6 in.	-
Disbonded area	-	8 sq. in.	-	5 sq. in.
**Impact test at 77F 650-g ball, 8-ft. drop, AWWA C203, Sec. 2.8.13				
Direct impact, disbonded area	-	16 sq. in.	-	10 sq. in.
Indirect impact, disbonded area	-	6 sq. in.	-	2 sq. in.
+Peel test, AWWA C203, Sec. 2.8.12	No peeling		No Peeling	

*For static conditions above 5F use enamel with 5-10 penetration at 77F; below 5F and above -10F use 10-15 penetration; and below -10F and above -20F use 15-20 penetration enamel. ("Static conditions" are those conditions under which the pipe is not being handled.)
**Choice of bond testing methods by deflection (before heating), by deflection (after 2-hr. heating), or by impact shall depend upon laboratory equipment available.
+Type I enamel in the 5-10 penetration range at 77F shall be tested with synthetic primer, Type B.
N/A = Not Applicable
SOURCE: AWWA C203-73.

TABLE B-2

AWWA REQUIREMENTS FOR COLD APPLIED TASTELESS AND ODORLESS COAL TAR BASED PAINT SUITABLE FOR LINING POTABLE WATER STORAGE TANKS

CHARACTERISTIC	SPECIFICATION
Viscosity - seconds per 100 revolutions @ 77°F (ASTM D-562)	60 - 75
Density, lb/gallon	8.7 - 9.7
Ash Content, % by weight	0.5 maximum
Flash Point (ASTM D-56)	70°F minimum
Distillate, % by weight (ASTM D-20)	45% maximum

Source: AWWA, 1964

TABLE B-3

COMPOSITION OF COAL TAR EPOXY COATING SUITABLE FOR USE IN POTABLE WATER STORAGE TANKS

INGREDIENT	% BY WEIGHT
COMPONENT ONE	
Coal Tar Pitch	34.0 - 36.0
Polyamide Resin* [2,4,6-Tri-(dimethylamino methyl phenol)]	11.0 - 12.0
Magnesium Silicate (ASTM D-605)	30.0 - 32.0
Xylene (ASTM D-364)	18.0 - 21.0
Ethyl Alcohol (95% denatured)	0.9 - 1.1
Gelling Agent	1.5
Catalyst	1.2 - 1.3
COMPONENT TWO	
Liquid Epoxy Resin (a di-epoxide condensation product of bisphenol A and epichlorohydrin with terminal epoxide groups)	Approximately 1 part of component 2 to 4 parts of component 1 by weight

Source: SSPC, 1973, with permission.

TABLE B-4

SPECIFICATION FOR COAL TAR PITCH
USED IN COAL TAR EPOXY PAINT

Characteristic	Specification
Softening Point, °C (ASTM D-36)	70 minimum, 75 maximum
Ash, % by weight (ASTM D-271)	0.5 maximum
Benzene insolubles, % by weight (ASTM D 367)	18.9 maximum
Volatiles, % by weight (ASTM D-20)	
Under 250°C	0
Under 300°C	5 maximum

Source: SSPC, 1973, with permission

TABLE B-5

SPECIFICATION FOR POLYAMIDE RESIN
USED IN COAL TAR EPOXY PAINT

Amine value*	330 minimum, 360 maximum

Source: SSPC, 1973, with permission.

*Amine value is defined as the milligrams of potassium hydroxide equivalent to the amine alkalinity present in one gram of sample. It is determined by a potentiometric titration with standard perchloric acid.

TABLE B-6

SPECIFICATIONS FOR GELLING AGENTS C AND D
USED IN COAL TAR EPOXY PAINT

Characteristic	Gelling Agent C	Gelling Agent D
Chemical Form	organic derivative of magnesium montmorillonite powder	microcrystalline hydrated magnesium silicate powder
Crystalline Form	-- *	Colloidal, rod shaped, submicron particles obtained by processing chrysotile
Bulking value	15 ± 2 pounds per gallon	--*
Density	--*	2.2 gm/cc
Refractive index	--*	1.5
Absorbed water, %	3.0 maximum	1.0
Surface area	--*	68 sq m/gm

*-- means no specification.

Source: SSPC, 1973, with permission.

TABLE B-7

SPECIFICATIONS FOR COMPONENT A OF
COAL TAR EPOXY PAINT

Characteristic	Specification
Viscosity, poise @ 25°C*	160
Nonvolatiles, %*	77 minimum

Source: SSPC, 1973, with permission.

TABLE 3-8

SPECIFICATIONS FOR COMPONENT B OF
COAL TAR EPOXY PAINT

Epoxide Equivalent (ASTM D-1652)	180 minimum, 200 maximum
Non volatile content, % one hour @ 105 ± 2°C	99 minimum
Color, (Gardner) (ASTM D 1544)	5 maximum
Specific gravity, 25°C/25°C	1.15 minimum, 1.18 maximum
Vicosity, poises @ 25°C (Brookfield)	100 minimum, 160 maximum

*Test procedures are described in reference.
Source: SSPC, 1973, with permission.

TABLE B-9

PHYSICAL PROPERTIES OF COAL TAR EMULSION

PROPERTY	TYPICAL VALUE
Specific Gravity	1.2
pH	6.2
Viscosity, Centistokes (ASTM D-562)	518
Vapor Pressure, Reid @ 25°C (ASTM D-323	3 psi
Flash Point (ASTM D-92)	
Cleveland Open Cup	131°C
Tag Open Cup	131°C
Firepoint	314°C
Resistance to flow with heat (Slide Test) (ASTM D-466)	No slide to 80°C
Sag	None at temperature to 80°C
Electrical Insulation	
Resistivity per cm thickness	3300 ohms
One mil thickness resists	600 volts

Source: Briggs Bituminous Composition Co.

TABLE B-10

A SINGLE COMPONENT EPOXY PAINT

Composition	Pigment - pure brown oxide Vehicle - modified epoxy
Viscosity @ 25°C	80-115 seconds, #4 Ford cup
Thinning	Not to exceed 10% by volume
Recommended thinner	Xylol
Solids by volume	38-39%
Solids by weight	60.0 $\pm$ 2%

Source: Sterling Division of Reichhold Chemicals, Inc.

TABLE B-11

TWO-COMPONENT EPOXY PAINT

HI-BUILD EPOXY UNDERCOAT

Composition:

Solids by weight - 75%

Pigment - Titanium dioxide and reinforcing pigments - 46%
Vehicle - epoxy resin solids - 29%

Solvent by weight - 25%
Solids by volume - 54-56%
Viscosity - 86-94 KU

EPOXY HARDENER

Composition:

Solids by weight - 66%

Pigment-reinforcing pigments - 47%
Polyamide solids - 19%

Solvent by weight - 34%
Solids by volume - 46-48%
Viscosity - 88-94 KU

MIXED MATERIAL DATA

Solids by weight	69.5 ± 0.5%
Solids by volume	50 - 51%
Thinning	Not to exceed 10% by volume
Drying time	16-24 hours @ 21°C
Pot life @ 21°C	8-10 hours

Source: Sterling Division of Reichhold Chemicals, Inc.

TABLE B-12

BASIC ZINC CHROMATE VINYL BUTYRAL WASH COAT

Pigment Base	% by weight
Polyvinyl butyral resin	9.2
Basic zinc chromate	8.8
Magnesium silicate	1.3
Lampblack	0.1
Butyl alcohol, normal	20.5
Isopropyl alcohol*	57.7
Water	2.4
Acid Dilutent	
85% Phosphoric acid	18.5
Water (maximum)	16.5
Isopropyl alcohol*	65.0

*Isopropyl alcohol and water in the pigment base may be replaced by ethyl alcohol, 61.3 parts. In the acid component it may be replaced by 67 parts of ethyl alcohol.

Source: SSPC, 1973, with permission

TABLE B-13

TYPICAL VINYL RESIN PAINT

Ingredient	Intermediate Coat % By Weight	Finish Coat % By Weight
Pigment:		
Titanium Dioxide*	12.0	0
Aluminum Powder	0	6.7
Vehicle:		
Vinyl Resin A**	8.0	7.5
Vinyl Resin B***	8.0	7.5
Tricresyl Phosphate or Dioctyl Phthalate	3.0	1.5
Methyl Isobutyl Ketone****	34.5	38.4
Toluene	34.5	38.4

*Lampblack or carbon black or stable durable tinting pigments may be substituted for a portion of the titanium dioxide when a tint or gray or dull black color is specified. The maximum content shall not exceed 5 percent by weight of pigment.

**Vinyl Resin A shall be a virgin, unprocessed hydroxyl containing vinyl chloride-acetate copolymer. It shall contain 89.5 to 91.5 percent vinyl chloride, 5.3 to 7.0 percent vinyl alcohol, and 2.0 to 5.5 percent vinyl acetate. The inherent viscosity of the resin (ASTM D-1243, Method A) at 20°C shall not be less than 0.5.

***Vinyl Resin B shall be a virgin, unprocessed carboxyl containing vinyl chloride-acetate copolymer. It shall contain 85.0 to 87.0 percent vinyl chloride, 12.0 to 14.0 percent vinyl acetate, and 0.5 to 1.0 percent maleic acid. The inherent viscosity of the resin (ASTM D-1243, Method A) at 20°C shall not be less than 0.48.

****Suitable high boiling vinyl resin solvents such as cyclohexanone may be substituted for a portion of the methyl isobutyl ketone if the paint is to be applied in hot atmospheric conditions or by brush.

Source: SSPC, 1973, with permission.

TABLE B-14

CHARACTERISTICS OF WAX PAINT SYSTEMS FOR LINING POTABLE WATER TANKS

Characteristic	Hot Applied Wax	Cold Applied Wax
Penetration @ 25°C		
ASTM D-937		200-250
ASTM D-5	30-70	
Melting Point, °C		
ASTM D-127	60-77	54-60
Solvent Content, %	None	20
Phenol, ppm	10	10

Source: Texaco, Inc.

TABLE B-15

COMPOSITION OF CHLORINATED RUBBER PAINTS
USED IN POTABLE WATER STORAGE TANKS

Ingredients	% By Weight Primer	Midcoat	Topcoat
Chlorinated Rubber Resin - Type A*	0.0	0.0	15.0
Chlorinated Rubber Resin - Type B*	10.2	12.1	0.0
Liquid Chlorinated Biphenyl***	5.6	6.0	6.0
Solid Chlorinated Biphenyl ***	2.7	3.0	3.6
Dioctyl Sebacate		0.0	1.5
Red Lead (97% Grade)	18.6	0.0	0.0
Zinc Yellow	3.1	0.0	0.0
Mica	3.1	3.9	0.0
Indian Red	0.5	0.0	0.0
Talc (Platy, Medium Consistency)	7.0	0.0	0.0
Organomontmorillonite**	1.3	0.4	0.0
Talc (Medium Consistency)	0.0	9.3	0.0
Rutile TiO_2	0.0	2.4	17.2
Lampblack	0.0	0.2	0.2
Toluene	47.9	62.7	28.2
Xylene	0.0	0.0	28.3
	100.0	100.0	100.0
Pigment Volume Concentration	38.2	30.0	20.0

*Type B - 67% chlorine and 17-25 at 20% concentration in chlorine at 25°C. (Example: Parlon S-20 for Type B, Parlon S-10 for Type A.)

**Example, Bentone 38,® registered trade name of National Lead Company.

Source: SSPC, 1973, with permission.

*** Chlorinated Biphenyls are no longer permitted to be used.

TABLE B-16

ASPHALT BASE OF SEAL COAT FOR CEMENT MORTAR LININGS

Characteristics of Asphalt Base	Typical Values
Specific gravity	1.035
Softening point	71 - 77°C
Penetration @ 25°C	15-25
Asphaltene content	28%
Saturated hydrocarbons	13%
Naphthene Aromatics and Polar Aromatics	59%
Benzo (a) pyrene & other suspect carcinogens in asphalt base	10 ppb
Nickel	80 ppm
Vanadium	550 ppm
Sodium	25 ppm

Source: The Gregg Co., Inc.

TABLE B-17

EPOXY PRIMER

Composition	Pigment - Pure iron oxide with inhibiting pigments Vehicle - modified epoxy
Viscosity @ 25°C	80-115 seconds #4 Ford cup
Thinning.	not to exceed 10% by volume
Recommended Thinner . . .	Xylol
Solids by volume	39-40%
Solids by weight	62 ± 2%

Source: Sterling Division of Reichhold Chemicals, Inc.

APPENDIX C

FDA LIST OF APPROVED POTABLE WATER TANK LININGS

NOTE: This list includes coatings that may be no longer be marketed. Its presence in this report does not imply that the coatings listed are acceptable for use in potable water systems at the present time.

CATEGORY 15: POTABLE WATER TANK LININGS

The following linings for potable water tanks are accepted solely on the basis that they contain no toxic ingredients which may be imparted to the water. Such acceptance is predicated on adherence to manufacturers' instructions for application.

1. Acryloid B-72, Rohm & Hass (Sinclair Refining Company, Marcus Hook, Pennsylvania) L-1014-57
2. Amercoat #33 (Amercoat Corporation, South Gate, California)
3. Amercoat #33 Gray (Amercoat Corporation, South Gate, California)
4. Amercoat #66 (Amercoat Corporation, Brea, California)
5. Apexuir #3 (Damphey Company, Boston, Massachusetts)
6. Bakelite Resin Aluminum 5504 (Inertol Company, Inc., Newark, New Jersey)
7. Ballastite #5953 (Farboil Company, Baltimore, Maryland)
8. Ballastite #7340 (Farboil Company, Baltimore, Maryland)
9. Ballastite #7386 (Farboil Company, Baltimore, Maryland)
10. Bisonite "M"
11. Butyl B44 Rubber Compound (F.P.T. Industries Ltd., Portsmouth, England)
12. Carboline Epoxy 154 F.G. (Carboline Company, St. Louis, Missouri)
13. Cement Wash
14. Coal Tar-epoxy Black Paint (Corps of Engineers Paint & Corrosion laboratory, Rock Island, Illinois)
15. Collodial Natural Flake Graphite "K-43" (Kograf Corporation, New York, N.Y.)
16. Devran Coating #207 (Version B) (Devo & Reynolds Company, Inc., New York, New York)

17. Durabel Tank Coating #679 (Peroline Company, Inc., New York, New York)

18. Durabel Primer #8493 (Perolin Company, Inc., New York, New York)

19. Ensign 395 (Ensign Products Company, Cleveland, Ohio)

20. Epon 828 (Shell Chemical Corporation, New York, New York)

21. Epoxy Activator #6330 (Pratt & Lambert, Inc., Buffalo, New York)

22. Epoxy Coating #836-R-10 (Cook Paint & Varnish Company, Kansas City, Missouri)

23. Epoxy Red Lead Primer #347 (Pratt & Lambert, Inc., Buffalo, New York)

24. Epoxy Resistant Coating, Black #0483, (Pratt & Lambert, Inc., Buffalo, New York)

25. Epoxy Resistant Coating, Silver Gray #71513, (Pratt & Lambert, Inc., Buffalo, New York)

26. Epoxy Resistant Coating, Dark Gray #71512, (Pratt & Lambert, Inc., Buffalo, New York)

27. Epoxylite BC 963, (The Epoxylite Corporation, South El Monte, California)

28. Epoxylite BC 964, (The Epoxylite Corporation, South El Monte, California)

29. Epoxylite BC 965, (The Epoxylite Corporation, South El Monte, California)

30. Epoxylite 203, (The Epoxylite Corporation, South El Monte, California)

31. Epoxylite 211, (The Epoxylite Corporation, South El Monte, California)

32. Eureka Fluid Film, Grade WT (Eureka Chemical Company, San Francisco, California)

33. Farbertite (Briggs Bituminous Composition Company, Philadelphia, Pennsylvania)

34. Farbo-Coat #73 (The Farhail Company, Baltimore, Maryland)

35. Farbo-Coat #64 (The Farhail Company, Baltimore, Maryalnd)

36. Fed-Cote (Pioneer Latex & Chemical Company, Inc., Middlesex, New Jersey)

37. Formula C-200 (Corps of Engineers Paint & Corrosion Laboratory, Rock Island, Illinois)

38. Formula T2908 (Red Hand Paint Company, New York, New York)

39. Fresh Water Paint No. 1810 (International Paint Co., Inc., New York, NY)

40. Gilsonite Asphalt Coating #827 (Detroit Graphite Company, Lyons, Illinois)

41. HERESITE P-403 (Heresite & Chemical Company, Manitowoc, Wisconsin)

42. Horsey-Set (Horsey, Robson & Company, Inc., New York, New York)

43. Inertol No. 49 Thick (Inertol Company, Inc., Newark, New Jersey)

44. Intergard Solvent Free Blue 4421 (International Paint Co., New York, NY)

45. Intergard Solvent Free Reactor 4423 (International Paint Co., New York, NY)

46. Intergard Solvent Free White 4424 (International Paint Co., New York, NY)

47. Jennite J-16 (Maintenance, Inc., Wooster, Ohio)

48. Jennite J-16-R (Maintenance, Inc., Wooster, Ohio)

49. Kata-Pontex Enamel (Intertol Company, Inc., Newark, New Jersey)

50. KOLMETAL (Emjay Maintenance Engineers, Rutherford, New Jersey)

51. Koppers Bitumastic Tank Solution #C-63240-BS-A-1477 (Koppers Company, Inc., Westfield, New Jersey)

52. Liquid Stainless Steel (Lockrey-Fater Corporation, New York, New York)

53. Napko Durachlor Fresh Water Tank Enamel 5014 White (Napko Paint & Varnish Works, Houston, Texas)

54. Napko Fresh Water Tank Enamel #2360 Metallic Brown (Napko Paint & Varnish Works, Houston, Texas)

55. Navy Formula #26

56. Navy Formula #102

57. NO-OX-ID "A Special" (Dearborn Chemical Company, Chicago, Illinois)

58. Orange Phenolic Primer 6261 (Humble Oil & Refining Company, Houston, Texas)

59. Palmer 7078 Epoxy Coating (Palmer Products, Inc., Worcester Pennsylvania)

60. Pitt Chem Amide Cured Coal, Tar Epoxy Coating (Pittsburgh Chemical Co., Pittsburgh, Pennsylvania)

61. Pitt Chem Coal Tar Urethane Coating (Pittsburgh Chemical Co., Pittsburgh, PA)

62. Pitt Chem Coating Powder, (Pittsburgh Chemical Co., Pittsburgh, PA)

63. Pitt Chem Permapipe Compound (Pittsburgh Chemical Co., Pittsburgh, PA)

64. Pitt Chem Tarset Primer (Pittsburgh Chemical Co., Pittsburgh, PA)

65. Pitt Chem TARSET Red (Pittsburgh Chemical Co., Pittsburgh, PA)

66. Pitt TARSET Standard- Coal Tar Epoxy Coating (Pittsburgh Chemical Co., Pittsburgh, PA)

67. Rigortex No. 3305 Enamel Finish (Inertol Company, Inc., Newark, New Jersey)

68. Rigortex No. 3305 Intermediate (Inertol Company, Inc., Newark, New Jersey)

69. Rigortex No. 3305 Primer (Inertol Company, Inc., Newark, New Jersey)

70. Rigortex No. 3313 Enamel Finish (Black & Aluminum Finish only), Inertol Company, Inc., Newark, New Jersey)

71. Rigortex No. 3313 Primer (Inertol Company, Inc., Newark, New Jersey)

72. Rigortex No. 3324 Enamel Finish (Black & Aluminum Finishes only) (Inertol Company, Inc., Newark, New Jersey)

73. Rock-Tar T.O. (Detroit Graphite Company, Lyons, Illinois)

74. Rust-Ban PH 6297 or 6297 (Humble Oil & Refining Company, Houston, Texas)

75. Rust-Oleum Series 400 to 499 (Rust-Oleum Corporation, Evanston, Illinois)

76. Rust-Oleum #9323 Aqua Blue (Rust-Oleum Corporation, Evanston, Illinois)

77. Rust-Oleum #9332 Aqua Green (Rust-Oleum Corporation, Evanston, Illinois)

78. Rust-Oleum #9334 Green Zinc-Sele (Rust-Oleum Corporation, Evanston, Illinois)

79 Rust-Oleum #9374 Orange Primer (Rust-Oleum Corporation, Evanston, Illinois)

80. Rust-Oleum #9384 Light Gray (Rust Oleum Corporation, Evanston, Illinois)

81. Rust-Oleum #9385 Gray Zinc-Sele (Rust Oleum Corporation, Evanston, Illinois)

82. Rust-Oleum #9390 White Primer (Rust-Oleum Corporation, Evanston, Illinois)

83. Rust-Oleum #9392 White (Rust-Oleum Corporation, Evanston, Illinois)

84. Sarva Compound - Sarva Acid Resisting Paint

85. Serviron

86. Sherwin-Williams Coating F52 A A8 (Sherwin-Williams Co., Washington, D.C.)

87. Socony-Vacuum Product #2305 (Socony-Vacuum Oil Co., Inc., Washington, D.C.)

88. Special Laykold Binder Formula #510 (American Bitumuls & Asphalt Company, San Francisco, California)

89. Sure Seal Butyl Rubber Membrane (Carlisle Tire & Rubber Division of Carlisle Corporation, Carlisle, Penssylvania)

90. Texaco Rustproof Compound H* (Texaco, Inc., New York, New York)

91. Texaco Rustproof Compound L (Texaco, Inc., New York, New York)

92. Tenec #199 (Tnemec Company, Inc., Kansas City, Missouri)

93. Unitite (Acorn Refining Company, Cleveland, Ohio)

94. Valdura #584 Sarva Liquid Black (Martin Marietta Corp., Kankakee, Ill.)

95. Valdura #585 Sarva Liquid Red (Martin Marietta Corp., Kankakee, Illinois)

96. Vinoplast Topcote (Lockrey-Frater Corporation, New York, New York)

97. Vinyl Primer Red (International Paint Co., Inc., New York, New York)

98. Vinyl White (International Paint Co., Inc., New York, New York)

99. Zinc Dust Base Paint #2406 (International Paint Co., Inc., New York, NY)

100. Zinc Dust Primer - Formula #102 (Mil. Spec. 15145)

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*Acceptance predicated on use below 125° F.

APPENDIX D

APPLICATION PROCEDURES FOR PIPE AND TANK LININGS

The procedures presented in this Appendix are only a brief summary of the detailed procedures found in the literature. They are included for information only. Before painting any pipe or tank, the detailed guides furnished by the paint manufacturer, the Steel Structures Painting Council, the National Association of Corrosion Engineers, and/or the American Water Works Association should be consulted.

D.1 Hot Applied Coal Tar Enamel

Linings can be applied in the shop or in the field. Storage tanks, because of their large size, are usually erected in the field and lined in place. Pipe sections up to about 10 feet in diameter can be lined in the shop and, depending on the method of assembly, may need to be touched up in the field. If the pipe sections are to be joined by welding, the practical minimum pipe diameter for enamel lined pipe is 27 inches where only the joints have to be lined in the field. If mechanical joining methods are used, the entire length of the pipe can be coated in the shop since the lining at the joined ends will not be damaged by the heat of a welding operation. The hot applied coal tar enamel can then be used in pipes as small as 4 inches in diameter. Because better control can be exercised over shop applied linings, the quality of shop lining is better. Also, the cost of applying the lining is lower because it can be applied at a faster rate. On the other hand, field application has an advantage in that damage to the lining from handling prior to installation is avoided.

After cleaning the metal surface by pickling or blast cleaning (commercial blast cleaning as a minimum), a primer coating is applied. Two types of primer are covered in AWWA standard C-203 (1973). One is a coal tar based primer consisting of an unfilled coal tar pitch cut back with a coal tar distillate. It is similar to the cold applied coal tar paint (tasteless and odorless) described in

Table B-2. It can be applied by brushing, roller coating or spraying and gives a 0.002 inches thick coating covering about 400 square feet per gallon.

The other primer is a synthetic resin based on chlorinated rubber. It has many advantages over the cold applied coal tar primer and is now almost universally used as the primer for hot applied coal tar enamel lining systems. The synthetic resin is a low solids lacquer-like material applied to a film thickness of about 0.001 inches. Care is required when spraying the primer so that a uniform sag-free coating of the desired film thickness is obtained. The enamel may be applied up to 2 weeks after the primer coat is dry. Five days is specified in the AWWA standard.

If the primer is shop applied to the metal plates that will be used to construct a tank, it should not be applied to the edges that will be welded. Field weld seams are to be blast cleaned and primed after erection. This also applies to the edges of pipes that will be joined by field welding.

Shop lining of steel pipes with hot coal tar enamel is done by a spinning process. The properly melted coal tar enamel* is introduced by a weir or by a trough which is inverted to pour the hot enamel lengthwise along the revolving pipe. It is important that the enamel

*Care must be used in melting or heating the enamel so as not to coke the enamel. Too high a temperature, or prolonged heating can embrittle the enamel and render it less serviceable and more susceptible to damage from handling (Bureau of Reclamation, 1976).

be at a temperature between 475°F and 500°F in order to obtain a well-bonded, uniform coating.

The average thickness of the coating should be 0.094 inches. If the coating is too thick it is more susceptible to cracking in cold weather and sagging in warm weather and to separation from the steel substrate.

Large diameter pipes, storage tanks, and pipe fittings are lined by hand daubing with tampico fiber daubers. The hand applied lining is applied in two coats to a total thickness of 0.094 inches. After application, the lining should be inspected with an electric flaw detector to locate voids or missed spots which must subsequently be repaired.

The vapors from the hot applied enamel will condense on cold surfaces in the tank. Before placing the tank in service, the surfaces of the tank that have been exposed to condensing vapors should be thoroughly flushed to avoid contaminating the water (Steiber, 1978).

D.2 Cold Applied Coal Tar Paint

Cold applied coal tar paint is applied to steel which has been pickled or subjected to at least a commercial blast cleaning. The paint can be applied directly to an unprimed surface. If a primer is used, it should be the same primer as that used for the hot applied coal tar enamel described above.

A minimum of two coats of paint are applied by brushing, or spraying, to a film thickness of .032 to .040 inches. Brushing is preferred for the first coat. Satisfactory spray application requires the use of special spraying equipment designed for heavy bodied materials (Fair, 1956). Each coat of paint must be thoroughly dry before applying a subsequent coat to avoid entrapment of solvent. Twenty-four hours is considered a minimum drying time. During cool, damp weather, several days may be required between coats.

D.3 Cold Applied Tasteless and Odorless Coal Tar Paint

Cold applied coal tar paint that is tasteless and odorless is also applied to steel which has been pickled or subjected to commercial blast cleaning as a minimum. It is self-priming and applied in three coats to a total dry film thickness of 0.006 to 0.008 inches.

D.4 Coal Tar Epoxy

Coal tar epoxy paint is applied to steel which has been subjected to at least a commercial blast cleaning. The paint is prepared for application by mixing 1 gallon of liquid epoxy resin with 3.5 gallons of the component containing the coal tar pitch and curing agents, fillers and solvent. The two paint components should be mixed vigorously for at least 2 minutes with a power agitator equipped with a 3-inch or longer blade (SSPC, 1973). If it is necessary to thin the paint for spray application, only xylene should be used. Not more than 1/2 gallon of xylene should be added to the 4.5 gallon mixture. The paint should be applied as soon after mixing as practical since

the mixture reacts chemically and will thicken substantially over a 2-hour period. It is a good practice to mix no more than can be applied in a 2-hour period.

The temperature of the surface to be painted should be no less than 50°F during application and for 5 days following. Use during hot weather when temperatures exceed 90°F is also undesirable as the pot life of the material is shortened considerably.

The coating is usually applied by spray in two coats to a minimum dry film thickness of 0.016 inches. The minimum drying time between coats is 12 hours. The paint develops a hard glaze relatively quickly which can inhibit adhesion of a second coat; therefore, a maximum of 72 hours drying time is suggested under normal circumstances. During hot weather, the time between coats may have to be shortened to 24 hours. On external surfaces exposed to sun and wind, it may be necessary to apply the second coat within 6 hours.

D.5 Coal Tar Urethane Paint

Application procedures for coal tar urethane paints are similar to those used for coal tar epoxy. For water immersion, a special primer coat may be required (SSPC, 1973). Urethane paints cure better than epoxy paints at low temperatures. It has been reported that urethane coatings have cured at temperatures as low as 2.2°F (Brown, 1973). Urethane paints also cure faster than epoxy. It is recommended that 8 to 14 days be allowed before contact with potable

water because the solvents used with urethane paints are slow to evaporate (Wallington, 1971).

D.6 Cement Mortar Lining of Pipe

Cement mortar linings are usually shop applied to pipes by a spinning (centrifugal) lining process. The process consists of feeding the mortar slurry into the bore of a rapidly rotating pipe so that the mortar is spread uniformly over the pipe bore by centrifugal force. After the mortar is in place, the pipe continues to rotate for about 90 seconds to compact the lining. The pipe is then removed from the rotating mechanism and inclined slightly (about 10°) to allow excess water to drain away. A smooth lining of uniform thickness is obtained and a continuous layer of cement mortar is produced over the pipe bore with minimal sand segregation and a surface substantially free from a cement-rich layer. Such a layer can form if spinning continues for too long a time. The pipes are usually held in the lining shop overnight after lining to protect them from extremes of temperature and humidity while in the "green" state.

The cement mortar can also be applied by a spray process. In this process, a centrifugal applicator head, situated at the end of a lance that is supported on a wheeled carriage, is pushed through the pipe. The mortar mix is pumped through the lance to the applicator head which throws the mix onto the pipe surface. The rate at which the lance is drawn through the pipe controls the thickness of the lining. The lining can be smoothed by rotating the pipe for about a

minute or by use of a drag trowel. The spray process is usually used for lining pipe in the field. Fittings are lined with cement mortar by hand and trowel. The lining mix is varied slightly depending on the size of the pipe, and the application process, as shown in Table D-1. A leaner mix is used in larger pipes to avoid the risk of shrinkage cracking. A richer mix is required for the spraying process to improve "flowability." The richer mix tends to give higher shrinkage contractions than the normal spinning mix (Padley, 1975).

In order to cure properly, the cement mortar lining must remain moist while curing. The ANSI standard for cement mortar lining of cast iron and ductile iron pipe suggests applying a bituminous seal coat material to the moist lining to inhibit moisture loss during curing (ANSI, 1974). Petroleum derived asphalt based coatings are commonly used as a seal coat. The components of an asphalt based seal coat are asphalt, mineral spirits and xylene. A typical asphalt base is characterized in Appendix B, Table B-16.

In addition to aiding the curing process, the seal coat also protects the cement mortar from decalcification in soft (calcium dissolving) waters. Although the decalcification process does not seriously damage the pipe, the increase in alkalinity of the water gives the water a flat, unpleasant taste and produces a staining of aluminum kitchen utensils. It may also affect the quality of products made with the water (Padley, 1975).

TABLE D-1

CEMENT MORTAR LINING MIXES

COMPONENT	CENTRIFUGAL LINING OF ≤ 200 mm DIAMETER PIPE (parts by weight)	CENTRIFUGAL LINING OF ≥ 200 mm DIAMETER PIPE (parts by weight)	HAND AND TROWEL LINING OF FITTINGS (parts by weight)
Cement	100	100	100
Sand	150	200	120 - 180
Water	55	55	40

The AWWA standard for cement mortar lining of steel pipe does not include this curing option (AWWA, 1971). In steel pipe, one of three methods is used: sealing the ends of the pipe; spraying the lining with water; or alternating applications of steam and water to the lining (AWWA, 1971).

A cement mortar lining is less sensitive to variations in substrate quality or application procedures than other linings (Padley, 1975). The pipe surfaces must be cleaned to remove loose or other foreign matter and there should be no projections which may protrude through the lining (ANSI, 1974; AWWA, 1971). Cement mortar has been successfully used over existing failed linings where only loose portions of the failed lining were removed before applying the cement mortar (Goulding, 1975).

D.7 Epoxy Paint Systems

Epoxy linings can be applied to pipelines in the field or in a shop. If the pipeline is to be welded, field application after the pipe is in place and all welding is complete is preferred. This is because the internal lining will be burned off at the weld joints. In small pipe it is not practical to repair the lining and in larger pipelines repair is time-consuming and impedes construction progress (Crawshaw, 1975). The surface of the steel must be chemically cleaned or commercial blast cleaned, leaving an etched surface to ensure permanent adhesion of the lining (Crawshaw, 1975). The surface is then neutralized, phosphatized, completely dried and

immediately coated with epoxy. The epoxy is allowed to dry and additional coatings are applied until the desired thickness is obtained. The lining is allowed to cure before being placed into service. A 0.002 inch zinc silicate base coat can be used instead of phosphate treatment to inhibit corrosion and improve adhesion of the epoxy lining. The dry film thickness of the epoxy over the zinc silicate is 0.006 to 0.008 inches (Cook, 1977).

One method of applying the epoxy to pipe interiors is by forcing the paint through calibrated orifice openings in pigs in the correct quantity against the pipewall as the pig is propelled through the pipe by compressed air. Relatively uniform film thickness and complete coverage is obtained. A wiper pig is used to smooth the surface and collect excess epoxy. The epoxy should not be applied if the temperature of the pipe is less than 40°F (Crawshaw, 1975).

In storage tanks, a typical single component epoxy paint is applied as a 3-coat system with a minimum dry film thickness of 0.00425 inches. The first or primer coat is an epoxy paint containing a corrosion-inhibiting pigment such as iron oxide. A typical primer is characterized in Appendix A. The primer is spray applied over commercial blast cleaned or pickled steel to a thickness of 0.0015 to 0.002 inches. The remaining coats should be applied to a dry film thickness of 0.0015 inches each. At least 24 hours of drying time should be allowed between each coat. The total dry film thickness must be at least 0.00425 inches or additional coats will have to be applied.

The temperature range for applying this epoxy system is 35° to 90°F. The relative humidity should be less than 80 percent. No problems have occurred when this paint is applied in a thick film over warm metal surfaces.

The tank should be allowed to dry for at least 5 days at atmospheric temperatures at 20°F or higher.

The two-component epoxy system specified in the AWWA draft proposed standard for painting steel tanks (AWWA, 1977) is applied in 2 or 3 coats to dry film thickness of 0.008 inches. Although the AWWA standard considers commercial blast cleaning or pickling to be adequate surface preparation, paint manufacturers recommend near-white blast cleaning for the two-component epoxy system (Sterling, 1977; Tnemec, 1977). The prime coat is spray applied to a dry film thickness of 0.003 inches and additional coats are spray applied to a total dry film thickness of 0.008 inches. At least 24 hours drying time at 60°F is recommended to allow for proper curing and adequate solvent release. Forced ventilation is recommended to accelerate solvent release and removal from the tank..

These high-build epoxy system should not be applied at ambient temperatures below 60°F. The relative humidity must not exceed 85 percent. The coating must be allowed to cure for a 7- to 10-day period at atmospheric temperatures of 60°F or higher before the tank is filled with water.

D.8 Vinyl Paint

For best performance it is generally recommended that near-white blast cleaning or pickling be used to clean the surface of steel to be protected with vinyl paint. If a wash coat is used (5-coat system) it should be brushed or sprayed on to the clear bare steel to a dry film thickness of 0.0003 to 0.0005 inches. The wash coat has a pot life of 8 hours and any material remaining after that time should be discarded. After drying (1/2 to 4 hours), the wash coat should be covered with a vinyl paint coat.

For systems not utilizing the wash coat*, the prime coat should be applied to the steel surface immediately after blasting, preferably by brushing. The remaining coats can be sprayed.

For all vinyl systems, the surface to be painted should be dry and above 35°F. The paint should be applied to obtain a 0.001 inch dry film thickness per coat. Air drying for 24 hours between coats is desired to allow for complete solvent removal. At least 48 hours drying time should be allowed before immersion. The ambient temperature should be 45° to 90°F for proper application and curing. The relative humidity must be less than 80 percent.

D.9 Wax

Wax coatings can be brushed or sprayed on to steel with little or no preliminary cleaning of the surface. It can be applied over old

*Wash primer is no longer recommended by most manufacturers for fresh water immersion service (SSPC, 1973).

rust, paint or rust-proof compound (Texaco, 1973). However, the AWWA standard for painting tanks (AWWA, 1964) recommends commercial blast cleaning of new tanks prior to application of the wax. The cold applied wax may be applied by thoroughly rubbing it onto and into the clean, dry surface with good, stiff-bristle brushes. Thorough wetting of the metal surface and displacement of moisture is desired. The cold applied wax may also be sprayed on using nonatomizing spray equipment. The wax must be heated to 30°F (or above its melting point) when spray applied. The wax is applied to a thickness of 0.020 to 0.030 inches and smoothed to eliminate brushmarks and holidays.

Hot applied wax is applied at a temperature of 30°F (or above the melting point) with a spray apparatus using fluid pressure through the nozzle. Prior to application the metal surface must be dried with a flame applied by a flared torch. After application, the lining is flashed or flamed by means of a torch to smooth out all laps and close any pinholes. The thickness of the lining is between 0.030 and 0.060 inches (AWWA, 1964).

D.10 Chlorinated Rubber

Commercial blast cleaning is the minimum degree of cleaning required for the application of a chlorinated rubber coating. However, it is recommended that a near-white blast cleaned surface be prepared for immersion service (White, 1978).

There are two primers available for use with this system. The chlorinated rubber primer, as specified by the AWWA, has been shown to produce better results (Christofferson, 1978). Nevertheless, a zinc-rich primer is widely recommended (Lombardo, 1978; White, 1978). The chlorinated rubber primer is applied to a maximum dry film thickness of .002 inches. The zinc rich primer is applied at up to 0.008 inches dry film thickness.

An intermediate coat of chlorinated rubber paint is applied to a dry film thickness of 0.002 to 0.005 inches after the primer has dried for at least 30 minutes. This coat can be topcoated after drying for 2 hours at 60° to 80°F. The topcoat has a dry film thickness of 0.0015 to 0.002 inches. The total system has a thickness of 0.006 inches according to AWWA specifications. Other proprietary systems can be as thick as 0.0095 inches (White, 1978). Waters (1978) claims that temperature and humidity conditions are not critical for application and that the coating can be applied at temperatures as low as 0°F. This is disputed by Koppers Company (1978) who states that ice on the surface to be coated can cause severe bonding problems.

All coats in this system are spray-applied. One of the advantages of using chlorinated rubber is the ease of applying new coats. Each new application softens the previous coat so that intercoat adhesion is excellent. Once the system cures, individual coats can no longer be distinguished.

D.11 Metallizing Zinc

Sprayed metal zinc is generally applied with a wire-fed gun consisting of an air or electric motor and suitable gears for feeding the metal wire through an oxygen gas flame. As molten particles tear away from the wire tip, they assume a spherical shape. The particles flatten when they strike the surface of the steel. Most of the bond is due to a mechanical interlock. It is important that a suitable anchor pattern be developed on the steel surface. This is accomplished by blast cleaning to white metal using one of three types of grit - salt free angular silica sand or crushed garnet, angular steel grit, or aluminum oxide as specified in AWWA standard D102-64, Section 3.8.3. To minimize deterioration in tank surface quality between sandblasting and metallizing, the metallizing operator can follow directly behind the sandblasting operator and apply the zinc coating to a section of the tank as soon as sandblasting of that section is completed (Warner, 1978). An average zinc thickness of 0.010 inches is applied.

APPENDIX E

DIRECTIONS FOR DETERMINING THE WATER EXTRACTABLE SUBSTANCES FROM A POLYMERIC OR RESINOUS WATER CONTACT SURFACE

NOTE: These procedures are currently being revised.

Convenient size pieces of the polymer or the coating applied to a suitable noncorrodable substrate should be prepared in a manner that they can be completely submerged in a container so that each surface will be in full contact with the extracting medium. The container should be of such a size that it will hold not less than 10 milliliters of volume of extractant per square inch of surface. Coating materials should be applied to the substrate at a time that will allow the extraction procedure to be undertaken at the minimum specified time of curing.

Prior to undertaking the extractions, the surfaces should be examined and carefully rinsed with deionized distilled water to remove any extraneous materials present. A solution of sodium hypochlorite containing a hundred parts per million of chlorine at pH 10.5 should be prepared using deionized distilled water and heated to a temperature of 70°F. The sample should be placed in contact with this solution for not less than 4 hours maintained at this temperature. The chlorine solution is then discarded and the sample again rinsed with deionized distilled water.

A sufficient amount of deionized distilled water is heated to a temperature of 120°F and poured over the samples until completely covered as before, the container covered with aluminum foil and the system maintained at 120°F for a period of 48 hours.* The extractant

*Note: Consideration is being given to lowering the test temperature to 90°F.

from 120 square inches of the polymer surface is evaporated to about 100 milliliters in a pyrex flask on a hot plate and then transferred to a clean, tared, platinum dish, flushing the flask three times with deionized distilled water to remove the last traces of the extractant. The latter is evaporated to a few milliliters on a low temperature hot plate and the last of the water is removed by evaporation in an oven maintained at 212°F. The platinum dish is cooled in a dessicator for 30 minutes and the residue weighed to the nearest tenth of a milligram. The amount of extractives is calculated as milligrams of extractive per square inch of surface. If this value turns out to be less than 0.5 milligrams per square inch, no further experimental work need be done. If the level is higher than that, the analyst may choose to make a determination of the chloroform soluble extractives described on page 464 of the Code of Federal Regulations, Title 21, Food and Drugs, Part loo to 199, revised as of April 1, 1977. (This text is printed below.)

Schedule of tests to be conducted.

1. Follow protocol above.
2. Follow protocol above.
3. Delete hypochlorite treatment.
4. Delete hypochlorite treatment.

Chloroform-Soluble Extractives Residue

Add 50 milliliters of chloroform (freshly distilled reagent grade or a grade having an established consistently low blank) to the dried and weighed residue in the platinum dish. Warm carefully,

and filter through Whatman No. 41 filter paper in a Pyrex funnel, collecting the filtrate in a clean, tared platinum dish. Repeat the chloroform extraction, washing the filter paper with this second portion of chloroform. Add this filtrate to the original filtrate and evaporate the total down to a few milliliters on a low temperature hotplate. The last few milliliters should be evaporated in an oven maintained at 212°F. Cool the platinum dish in a desiccator for 30 minutes and weigh to the nearest 0.1 milligram to get the chloroform-soluble extractives residue, e'. This is substituted in equation E-1 below:

$$\text{Milligrams extractives per square inch} = \frac{e'}{s} = e \qquad \text{(E-1)}$$

where s is the surface area of the coating, square inches and e' = milligrams extractives per sample tested. The value of "e" must not exceed 0.5 milligrams per square inch.