PLAINTIFF'S EXHIBIT

CAP-936

ASBESTOS-CEMENT PIPE

INTRODUCTION

A combination of portland cement, asbestos fibers, and silica produces the unique pipe material, asbestos-cement. Asbestos-cement pipe can be manufactured in all the sizes and strengths needed to meet the varied service requirements of the public-works, irrigation, industrial, and home-building industries.

An Italian engineer, A. Mazza, first developed an asbestos-cement pipe in 1913. Successful performance in fire protection systems led to rapid acceptance throughout Italy and the spread of asbestos-cement pipe manufacture to England in 1925 and to America in 1929.

The strength and durability of asbestos fibers have been known for centuries. The ancient Asiatics, Greeks, and Egyptians used asbestos for its resistance to fire, heat, most acids, the weather, and for its strength and durability. They learned to separate the fibers and weave cloth for clothing and other items. The intimate combination of portland cement and asbestos fibers develops a material that retains many of the inherent characteristics of the separate components.

Major uses of asbestos-cement pipe are in water distribution systems and sewage and waste-water collection and disposal systems for municipal and private utilities; in irrigation and drainage systems for agriculture; and in manufacturing process systems, potable and cooling water lines, and fire protection and waste collection systems for industry. Other important uses are for cable conduits in the electric power and communications fields and for heating, venting, and air-conditioning ducts in industrial and residential construction.

Asbestos-cement pipe offers outstanding advantages for use in all types of water conveyance systems. The inherent characteristics of asbestos-cement pipe contribute to overall economy from design to installation, operation, and maintenance. The long lengths, simple and efficient coupling details, strength, light weight, and corrosion resistance add up to construction and performance satisfaction at minimum cost.

The first manufactured pipe were used in gravity flow systems. Use of asbestos-cement pipe extended to pressure systems as the techniques of manufacture improved to increase the strength characteristics of the pipe.

PORTLAND CEMENT ASSOCIATION
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The activities of the Portland Cement Association are limited to scientific research, the development of new or improved products and methods, technical service, promotion and educational effort (including safety work), and are primarily designed to improve and extend the uses of portland cement and concrete. The manifold program of the Association and its varied services to cement users are made possible by the financial support of its member companies in the United States and Canada, engaged in the manufacture and sale of a very large proportion of all portland cement used in these two countries. A current list of member companies will be furnished on request.

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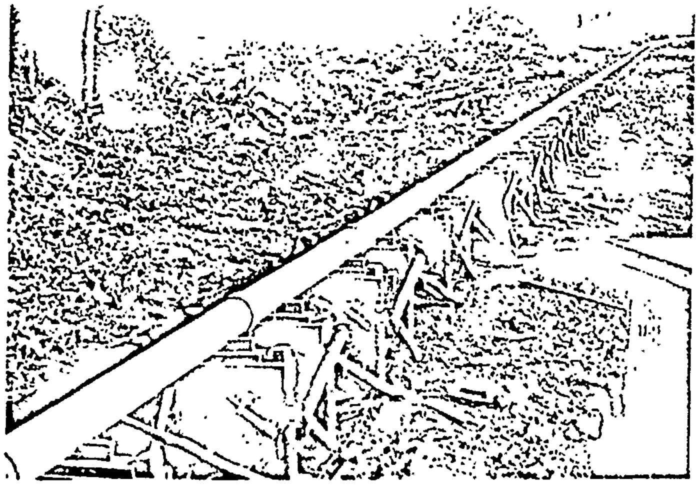

Above. **Waste disposal of acidic mining water is pumped through asbestos-cement pipe to an alkaline tailing pond.**
Courtesy Canadian Johns-Manville Co. Ltd.

Right. **Storm drain water installation utilizing a pliant plastic sleeve coupling. Perforated asbestos-cement drain pipe also adapts to this type of joint construction.** *Courtesy Johns-Manville.*

MANUFACTURE

Asbestos-cement pipe is manufactured from portland cement, asbestos fibers, and silica flour. Portland cement is finely ground powder composed of certain chemical compounds. When water is mixed with portland cement, it forms a cementitious paste that, upon hardening, binds materials together into a product with excellent compressive strength. Just as steel reinforcement is used to improve the tensile strength of hardened concrete, asbestos fiber is the reinforcement that provides the necessary tensile strength of asbestos-cement pipe.

Years of experience have proved that chrysotile asbestos is most suitable for pipe production, although asbestos made of other fibers is used to some extent. Individual chrysotile fibers, derived from a fibrous magnesium silicate, have a diameter of approximately 1 millionth of an inch. The strength of good asbestos fibers is equivalent to the strength of piano wire or to steel threads having a diameter of 40 millionths of an inch.

Portland cement, asbestos fibers, and finely ground silica are the ingredients of 20th-Century asbestos-cement pipe. The portland cement is thoroughly dry-mixed with the silica and selected asbestos fibers. Water is added and the wet-mix slurry is moved to a vat. There a rotating cylinder mold picks up a thin film of the mixture and transfers it to a felt conveyor where excess water is removed.

Next, the well-mixed, smooth slurry is fed in a thin layer onto revolving steel mandrels and compressed under pressure into a tough, homogeneous structure. The size of the mandrel determines the internal diameter of the pipe. When the desired wall thickness has been reached, the mandrel is loosened from the newly formed pipe.

Up to this point operations for all asbestos-cement pipe, regardless of size, length, or type, are the same except for the mix proportions. The blend used and thickness of the pipe wall depend on the strength requirements of the finished pipe. After loosening, the pipe and mandrel move slowly along a conveyor until an initial pre-cure hardness is attained. Then the mandrels are removed and the pipe placed in curing trays in a controlled temperature-humidity room to develop a primary hardness. The pipe is then ready for autoclave curing.

In the autoclave curing process, the pipe is placed in a pressure steam curing vessel. The pressure is built up to about 100 lb. per square inch and left under saturated steam conditions for several hours. This causes the finely ground silica to combine chemically with the free lime in the cement to form calcium silicates. Calcium silicates are highly stable, corrosion-resistant compounds. Autoclave curing also imparts maximum strength to the pipe.

After curing, the pipe ends are trimmed and machined on finishing lathes to exact dimensions to match couplings, thereby ensuring both tightness and ease of assembly. All couplings and fittings are made to the same rigid standards.

Quality control is adhered to in all steps of manufacture. All pipe are checked for compliance with specifications. Various strength tests are performed at the factory to assure that the pipe meets the requirements of its intended service.

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SPECIFICATIONS

In the United States and Canada, rigid specifications for the manufacture of asbestos-cement pipe were developed from practically the beginning of pipe production. Today's manufacturers make pipe of various strengths to meet many different design conditions.

Asbestos-cement pipe is manufactured to satisfy the chemical and physical properties required for a particular service with an ample margin of safety. Precisely controlled dimensions assist materially in installation economy and performance. Users of asbestos-cement pipe are ensured of a quality product for the job by selecting pipe to fit the job's specific needs.

A partial list of specifications of several organizations is provided in Table 1. The omission of specifications and organizations in this table has no significance. There are many specifications and space does not permit listing them all.

The American Society for Testing and Materials is nationally recognized for its specifications for many construction materials and processes. The American Water Works Association has developed nationally recognized standards for asbestos-cement pressure pipe usage in the waterworks industries. Other organizations also prepare specifications for various uses of asbestos-cement pipe. For further information on specifications, contact the local asbestos-cement pipe representative or a district office of the Portland Cement Association.

USES OF ASBESTOS-CEMENT PIPE

The type of materials and the manufacturing process give asbestos-cement pipe many advantages in water supply, waste water, irrigation, drainage, and other liquid and air conveyance systems. The many uses of the pipe are directly related to two distinct categories: pressure pipe and nonpressure pipe, both having excellent flow properties.

TABLE 1. **SPECIFICATIONS CONCERNING ASBESTOS-CEMENT PIPE**

Organization	Specification number	Title	Major subject
AWWA	H2	Standard Practice for the Selection of Asbestos-Cement Water Pipe	Loading conditions for water distribution systems
AWWA	C400	Tentative AWWA Standard for Asbestos-Cement Water Pipe	Pressure flow systems
AWWA	C603	Installation of Asbestos-Cement Water Pipe	Water distribution systems
ASTM	C296	Asbestos-Cement Pressure Pipe	Water, sewage, and other fluids carried under pressure
ASTM	C428	Asbestos-Cement Nonpressure Sewer Pipe	Gravity flow systems
ASTM	C458	Organic Fiber Content of Asbestos-Cement Products	Methods of testing
ASTM	C460	Terms Relating to Asbestos-Cement and Related Products	Definitions of terms
ASTM	C500	Asbestos-Cement Pipe	Methods of testing
ASTM	C508	Asbestos-Cement Perforated Underdrain Pipe	Subsurface drainage systems
ASTM	C1869	Asbestos-Cement Pipe, Rubber Rings for	Pressure and gravity systems
AASHO*	M189	Perforated Asbestos-Cement Pipe for Underdrainage	Subsurface drainage systems
Federal Spec.	SS-P-351a	Pipe: Asbestos-Cement	Pressure flow systems
Federal Spec.	SS-P-331a	Pipe: Asbestos-Cement, Nonpressure	Gravity flow systems such as sewers

*AASHO—American Association of State Highway Officials

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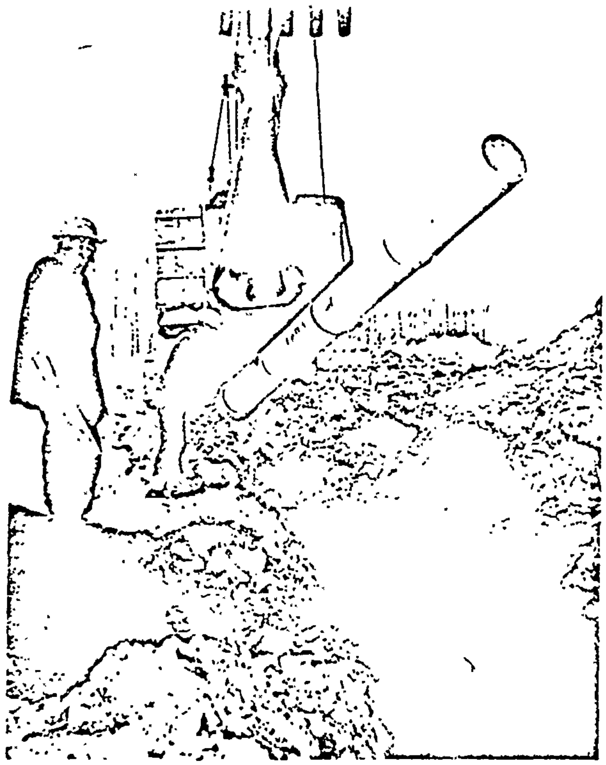
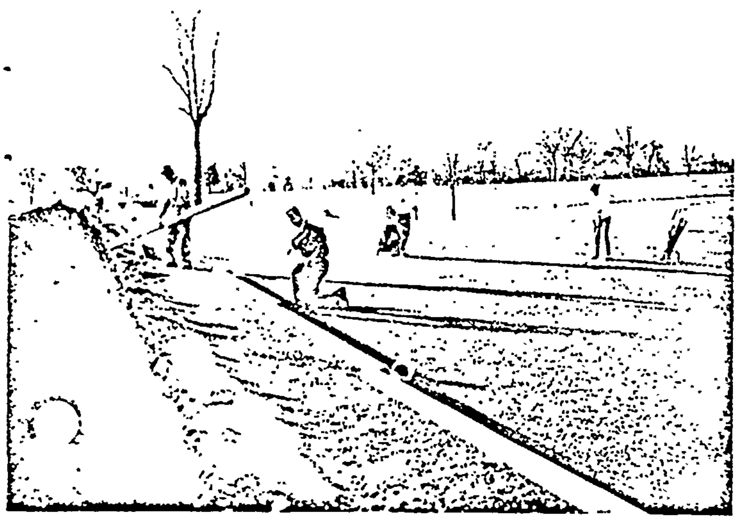


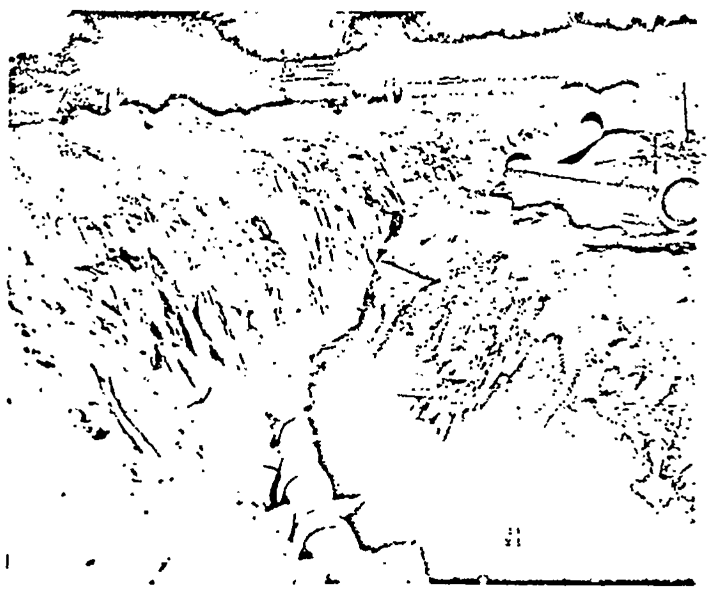
Asbestos-cement pipe adapts to winter installation for this gravity sewer system. The pipe is bedded on a pea gravel base in the rocky trench. *Courtesy Atlas Asbestos Co. Ltd., Canada*

A cast-iron valve is a standard, readily assembled control unit in asbestos-cement pressure water mains.
Courtesy Johns-Manville.

The Canton, Ill., Country Club irrigation system being installed with asbestos-cement pipe without interruption to the golf enthusiast. *Courtesy Certain-Teed Products Corp.*



Pressure-pipe installation shows how readily asbestos-cement pipe adapts in following the contours of the rolling landscape and avoiding obstacles. *Courtesy Certain-Teed Products Corp.*



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The flow equation most widely used by engineers in pipeline design is the Manning formula, which expresses the relationship of velocity to pipeline characteristics:

$$V = \frac{1.486}{n} R^{2/3} S^{1/2}$$

where n = measure of surface roughness
R = hydraulic radius
S = slope of energy gradient
V = average velocity

The Hazen-Williams formula is often used in pressure systems:

$$V = 1.318 C R^{0.63} S^{0.54}$$

where C = measure of surface roughness

Asbestos-cement pipe has a roughness value of $n = 0.010$ for the Manning formula and $C = 140$ for the Hazen-Williams formula. The low roughness value provides the designer a minimum energy loss due to resistance, and therefore maximum economy.

Equally important to the designer are the many classes of pipe for both internal and external loading. The pipe is designed, produced, and tested to meet definite strength criteria. The designer can select a pipe with the strength necessary to do the job and be assured of satisfactory performance. Internal pressure strengths are known from hydrostatic tests. External strengths, flexural and crushing, are factory-tested to ensure the required performance.

Pressure Pipe

Asbestos-cement pressure pipe is designed to carry liquids under pressure. It is widely used in municipal and private water utility service, in industrial service for both underground and overhead supply and waste lines, and in irrigation systems. Special applications include salt water collection and disposal lines in oil fields. Asbestos-cement pressure pipe has proved its performance under severe environmental conditions as drainage conduits for mining operations and as force mains in sewage lines.

Pressure pipe is manufactured to meet three internal pressure ratings. Each pipe and coupling is designed for sufficient strength to withstand an internal hydrostatic pressure of four times the rated working pressure for the class of pipe. Class of pipe denotes the internal working pressure. Therefore, Class 100 pipe is made to withstand internal pressures up to 100 psi; Class 150, 150 psi; and Class 200, 200 psi. A convenient relationship of pressure and waterhead is provided in Table 2.

In addition to the internal pressure, the pipe must withstand both flexural loads and crushing loads. These minimum loads are listed in Tables 3 and 4 for the three classes of pressure pipe. Design criteria for both internal and external loads are specified in AWWA H2, Standard Practice for the Selection of Asbestos-Cement Water Pipe.

The method of manufacture of asbestos-cement pipe ensures that the chemical and physical properties will meet the user's specification. Autoclaving virtually eliminates uncombined calcium hydroxide which ensures chemical stability and increases its resistance to corrosive elements. The cured pipe is trimmed and machined to required dimensions. Precisely controlled dimensions assist materially in installation economy and performance.

TABLE 2.
HYDROSTATIC PRESSURE FOR DIFFERENT WATERHEADS

Waterhead, ft.	Hydrostatic pressure, psi
10	4.33
20	8.67
30	13.00
40	17.33
50	21.67
60	26.00
70	30.33
80	34.67
90	39.00
100	43.33
150	65.00
200	86.67

TABLE 3.
FLEXURAL STRENGTH OF ASBESTOS-CEMENT PRESSURE PIPE (AWWA C400-64T)

Nominal diameter, in.	Total applied load, lb.*		
	Class 100	Class 150	Class 200
4	1,200	1,460	1,860
6	2,800	3,700	4,900
8	5,330	7,600	10,130

*Loads applied according to AWWA (C400) flexural test procedure.

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TABLE 4.
CRUSHING STRENGTH OF ASBESTOS-CEMENT PRESSURE PIPE (AWWA C400-64T)

Nominal diameter, in.	Applied load, lb. per foot*		
	Class 100	Class 150	Class 200
4	4,100	5,400	8,700
6	4,000	5,400	9,000
8	4,000	5,500	9,300
10	4,400	7,000	11,000
12	5,200	7,600	11,800
14	5,200	8,600	13,500
16	5,800	9,200	15,400
18	6,500	10,100	17,400
20	7,100	10,900	19,400
24	8,100	12,700	22,600
30	9,700	15,900	28,400
36	11,200	19,600	33,800

*Loads applied according to AWWA (C400) crushing test procedure.

TABLE 5.
NOMINAL SIZE AND CRUSHING STRENGTH OF ASBESTOS-CEMENT NONPRESSURE SEWER PIPE (ASTM C428-64T)

Pipe class	Applied load, lb. per foot*	Nominal diameter, in.
1,500	1,500	6, 8, 10, 12, 14, 16
2,400	2,400	6, 8, 10, 12, 14, 16, 18, 20, 24
3,300	3,300	6, 8, 10, 12, 14, 16, 18, 20, 24, 30
4,000	4,000	10, 12, 14, 16, 18, 20, 24, 30, 36
5,000	5,000	10, 12, 14, 16, 18, 20, 24, 30, 36

*Loads applied according to ASTM (C500) crushing strength test procedure.

Nonpressure Pipe

There are many classes and types of nonpressure pipe produced for private, municipal, federal, and industrial use. Nonpressure pipe serve many functions, such as gravity flow sewage conduits, underdrain pipe, storm drains, gas and plumbing vents, air ducts, and electrical transmission cable conduits. The pipe is produced to best fit the job application, including its chemical and physical requirements.

The ASTM C428 specification for asbestos-cement nonpressure sewer pipe can be used as a guide to the properties of nonpressure pipe. Asbestos-cement pipe in this specification are designated as Classes 1,500, 2,400, 3,300, 4,000, and 5,000. The numbers refer to the minimum crushing strength in pounds per foot for each class. Pipe sizes, classes, and strength requirements are given in Table 5.

Another ASTM strength test determines the ability of asbestos-cement nonpressure pipe to withstand bending or flexure. Each standard length of 6- and 8-in.-diameter pipe is required to withstand a minimum total flexural load as indicated in Table 6.

In addition to external strength requirements, the pipe must have sufficient internal strength to withstand hydrostatic pressure of 50 psi. In the hydrostatic pressure test the pipe must show no signs of leaking, weeping, or cracking. In each class designation three types of pipe are available with different allowable percentages of uncombined calcium hydroxide. Type I pipe cannot have more than 3 percent uncombined calcium hydroxide; Type II, 1 percent; and Type III, no limitation. These allowances are particularly important in corrosive water-sewerage conditions.

Variations of nonpressure pipe requirements can be specified when pipe is for use other than in gravity sewer systems. Reference can be made to manufacturers' specifications for the strength characteristics of pipe used in air ducts, electrical conduits, and many other systems.

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TABLE 6.

FLEXURAL STRENGTH OF ASBESTOS-CEMENT NONPRESSURE SEWER PIPE (ASTM C428-64T)

Nominal diameter, in.	Length, ft.	Total applied load, lb.*		
		Class 1,500	Class 2,400	Class 3,300
6	10	1,500	1,700	2,100
6	13	2,000	2,200	2,600
8	10	2,700	3,000	3,900
8	13	3,600	4,100	4,800

*Loads applied according to ASTM (C500) flexure strength test procedure.

Joints

Joints and jointing methods are important in any pipe installation. Manufacturers of asbestos-cement pipe supply a complete range of accessories for quick installation and safe, efficient performance of a pipe system.

Couplings for high-pressure systems are machined from the same pipe stock as the various classes of pipe. Straight-line joints are made virtually watertight by a rubber sealing ring that fits the machined pipe and couplings. Equally as important as the joints is the easy adaption of cast iron valves, elbows, tees, etc., into an asbestos-cement pipeline.

Use of plastic and rubber formed materials assists in construction of air duct pipe systems and storm drains. Asbestos-cement fittings also are available from these systems. Joint material and details are selected from the manufacturers' lists to best fit the needs of the installation.

INSTALLATION

Installation of asbestos-cement pipe proceeds swiftly. The combination of light weight, standard long lengths, and efficient couplings permits rapid construction. The pipe is easy to handle when trucking, moving, and installing, often resulting in small work crews. Pipe installations are further simplified with flexible joints that let the pipe readily conform to gradual changes in alignment and grade.

The precision couplings speed assembly and ensure watertightness in water and sewage lines. Rubber compression rings and machined couplings are pushed or pulled together with little difficulty. In addition, the couplings are designed to provide joint flexibility in the line to absorb deflection, curvature, severe vibration, and subsidence—and still remain watertight.

Asbestos-cement pipe can readily be drilled and tapped with ordinary waterworks tools to make service connections. When necessary, the pipe is easily cut and machined for connections to valves, fittings, hydrants, or other junctions. A wide range of shop-fabricated tees, wyes, and elbows simplify sewer, drain, irrigation, building sewer, air duct, and conduit line connections.

Watertightness is essential in water and sewage systems. The joint couplings and the pipe are thoroughly tested to ensure watertightness. The designed tightness, ensured with compression rubber rings, assures the engineer that the pipeline will meet rigid field infiltration tests.

Coupling assemblies for both pressure and nonpressure pipe service are easily made. Other joints of tapered sections, plastic sleeves, and wraparound tapes have serviceability for other uses of asbestos-cement pipe. There is an asbestos-cement pipe and pipe coupling specifically designed for each use. From high-pressure water mains to air conduits, the pipe and pipe couplings assure easy, rapid, durable, and economic construction.

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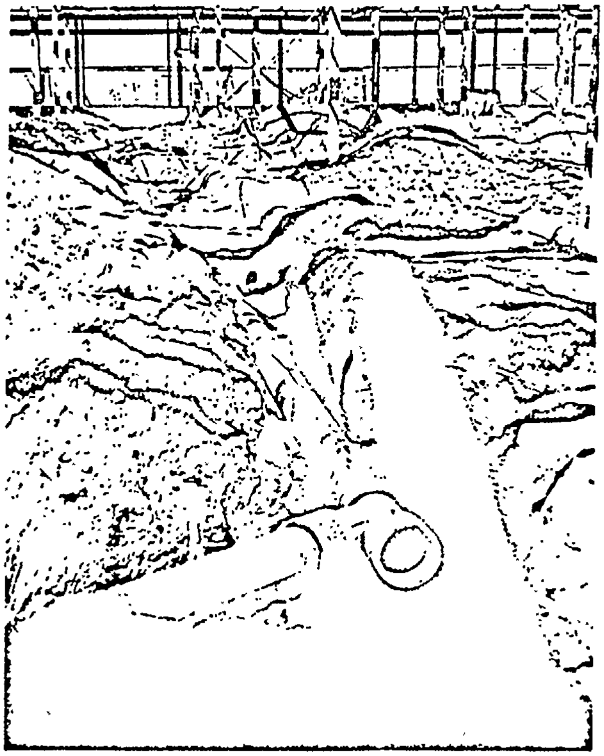
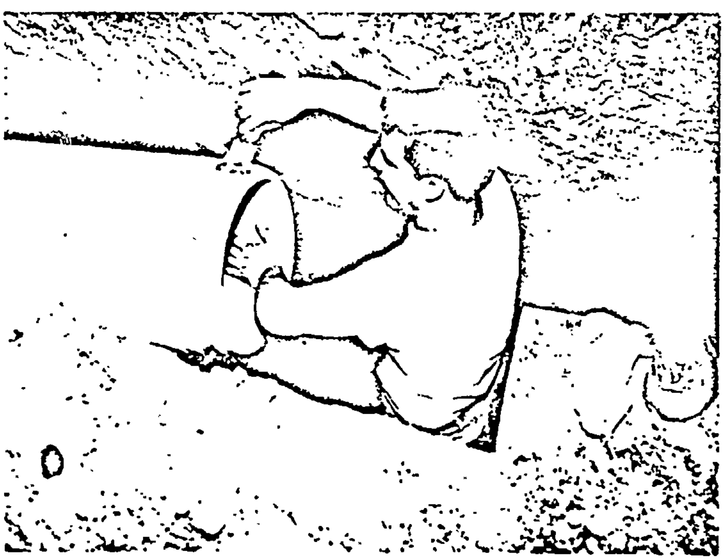


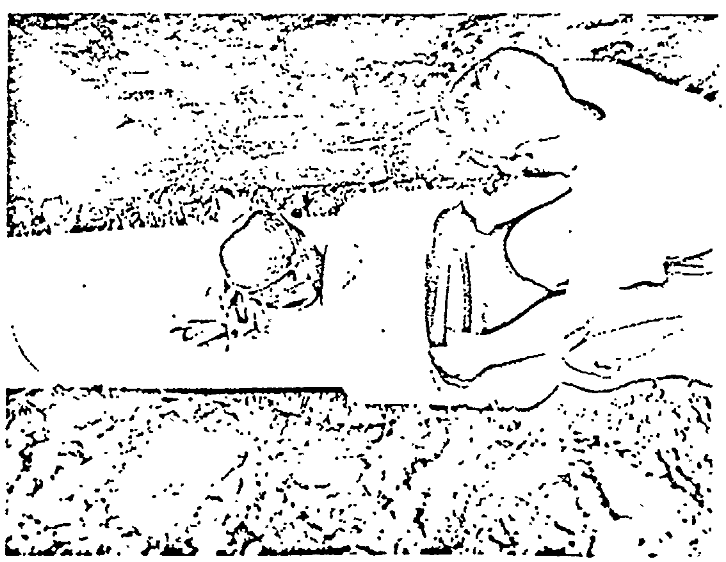
Plant-manufactured tees, wyes, and couplings permit rapid installation of industrial sewer drains. *Courtesy The Flintkote Co.*

House sewer line connections are easily accomplished with asbestos-cement pipe. The machined end is lubricated. Coupling with rubber gasket is positioned and pushed on with pry bar and block of wood. *Courtesy Certain-Teed Products Corp.*

Lubricant being applied to the end of a water pressure pipe to facilitate assembly. *Courtesy The Flintkote Co.*



A rubber compression ring ensures watertightness and flexibility of the pipe system. *Courtesy The Flintkote Co.*



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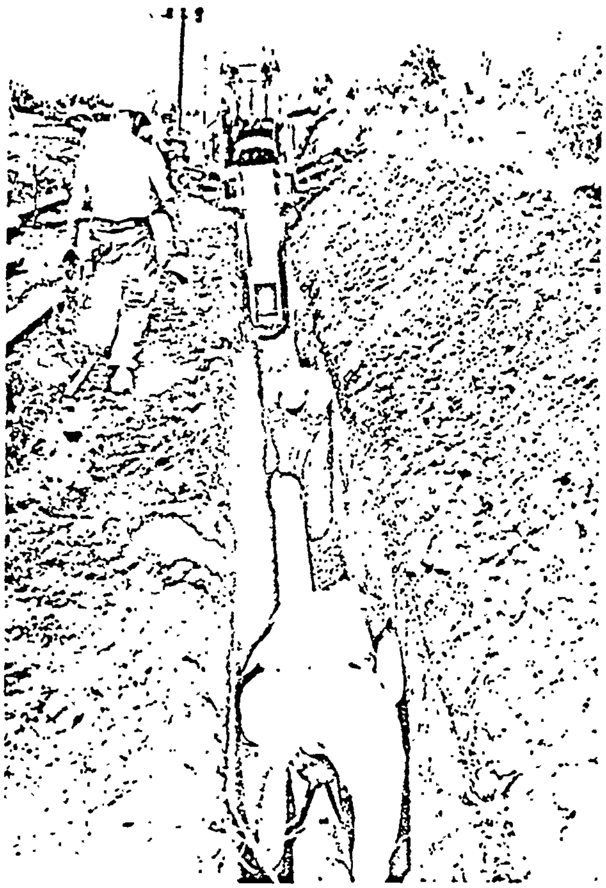

A section of pipe is easily aligned and assembled by two men. They are laying pipe as fast as the trench is being dug.
Courtesy The Flintkote Co.

This bank of asbestos-cement pipe will ensure watertightness for electrical cables. *Courtesy Canadian Johns-Manville Co. Ltd.*

OPERATIONAL ADVANTAGES

Asbestos-cement pipe offers many operational advantages over steel or cast-iron pipe. In water supply systems, transmission costs are held to a minimum because asbestos-cement pipe offer little resistance to flow. Pumping efficiency is maintained because asbestos-cement pipe will not tuberculate or rust, which causes an increase in roughness and decrease in pump efficiency. Similar efficiency and savings are secured in force mains for sewage lines and in irrigation pumping systems utilizing asbestos-cement pipe. Water supply lines are secured against excessive water loss and pressure reductions. Water is delivered when needed and at the required pressure with optimum economy.

Infiltration of water into sewage and storm drain lines often encroaches on the design capacity of the line. However, an asbestos-cement pipe system reduces the waste-water treatment plant load by keeping out this excess water that would have to be treated in systems of lesser quality construction. Moreover, watertightness prevents exfiltration of sewage and pollution of the groundwater through which many sewage lines must be built. In some areas the groundwater is used for residential, commercial, and industrial use; if it becomes polluted, it must have some type of treatment. The watertight asbestos-cement pipeline truly represents an operational saving.

MAINTENANCE ADVANTAGES

Watertight asbestos-cement pipe keeps out tree roots, a perpetual maintenance problem in many underground pipeline systems. Further maintenance economics are gained because asbestos-cement pipe's strength, smooth interior surface, and tight flexible joints provide a pipeline that stays sound and tight, requiring less frequent inspections.

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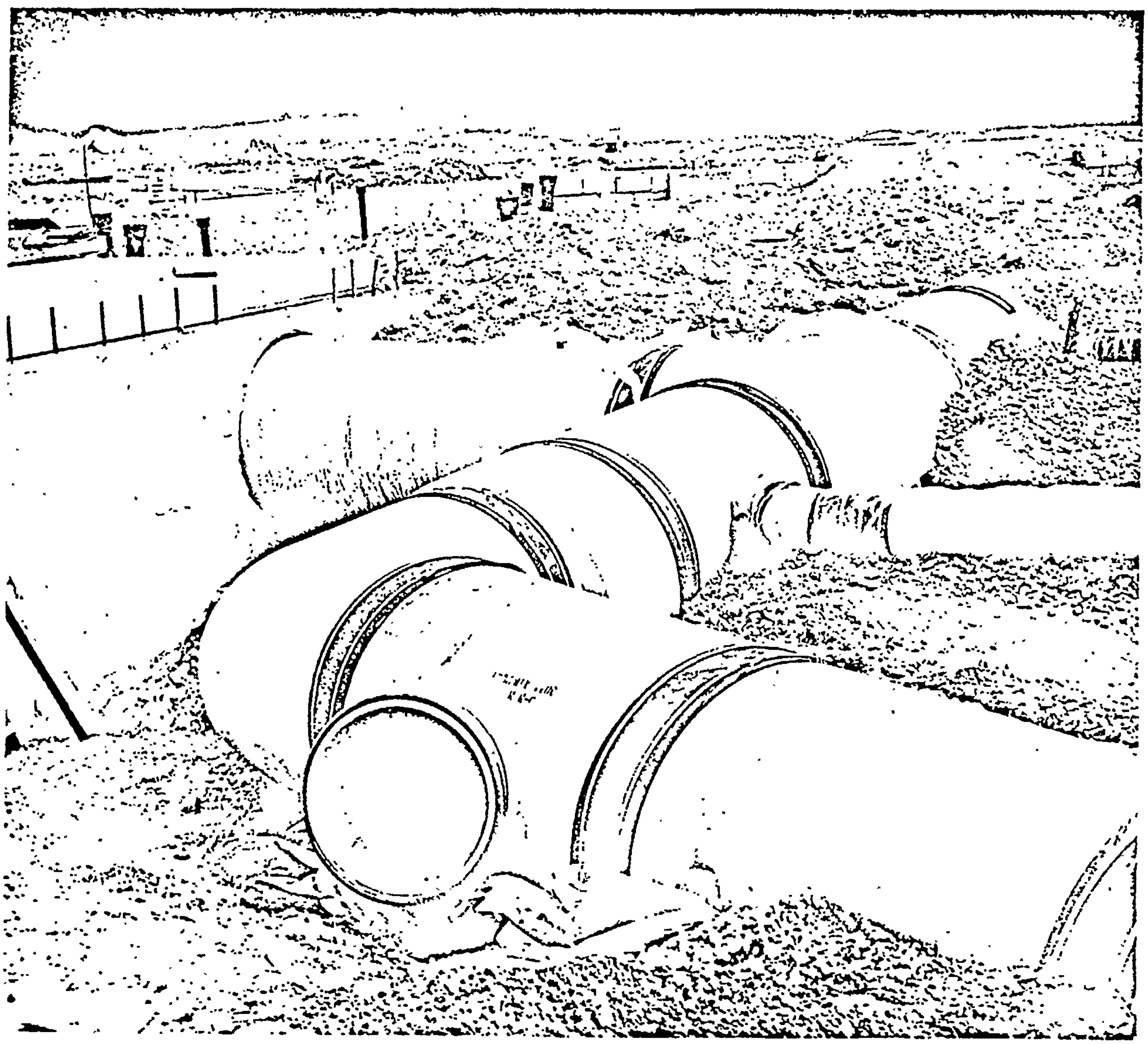
Because of the nature of its stable ingredients, asbestos-cement pipe resists many corrosive fluids and most aggressive soils. As a nonconductor, it is immune to electrolysis and electrochemical corrosion. Since it is corrosion-resistant throughout and will neither rust nor tuberculate, the design strength is maintained through years of maintenance-free service. Thousands of miles of asbestos-cement pipe now serving as sewer and water lines and in corrosive oil field and mining operations attest to its remarkable physical and chemical stability. These properties assure operation with minimum maintenance.

Similarly, the inherent characteristics of asbestos-cement pipe make it an ideal construction material for gas and plumbing vents, air ducts, and conduits for cables of various types. Heat, fire, corrosion, and rust resistance are essential to adequate safe and long service performance of these systems.

A large 30-in. asbestos-cement pipe is used for an air duct system. The pipeline is made virtually airtight with a pliant plastic sleeve coupling. This installation illustrates the various tees, elbows, and junction assemblies of an asbestos-cement pipe system.
Courtesy Johns-Manville.



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Hot air ducts of asbestos-cement pipe are cast into the floor slab for this home to give long-lasting heating and air-conditioning service.
Courtesy Johns-Manville.

SUMMARY

Proven in industries where the water carried is often highly aggressive, asbestos-cement pipe continues to have an enviable record for its outstanding economy. Its quality performance has been responsible for many new standards in the operation and maintenance of underground and exposed piping.

A brief summary of asbestos-cement pipe performance characteristics is given in Table 7 (on page 13) to assist you in weighing the many important advantages of asbestos-cement pipe.

OTHER ASBESTOS-CEMENT PRODUCTS

There are many other asbestos-cement products available for use in construction. Notable among these are siding and roofing products. Advanced manufacturing techniques provide siding and roofing sheets in many textures, colors, and a variety of shapes while maintaining the durability, corrosion resistance, strength, and workability characteristics of the pipe products.

Standard and lightweight corrugated panels have been produced for commercial and industrial use. These too retain the asbestos-cement characteristics of resistance to corrosion, fire, acid fumes, gases, and salt air, while providing ease in assembly and good strength properties.

Asbestos-cement has become a basic building material. It can be used from the foundation up and in the interior to subdivide the space and provide a pleasing, esthetic decor.

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C105

KEY WORDS: asbestos-cement products, conduits, drainage, installation, irrigation, manufacturing, pipe, sewers, specifications, water supply systems.

ABSTRACT: Provides information on specifications and operational advantages of abestos-cement pipe. Includes general information on the history of the industry and the manufacture and installation of pipe for various purposes. Illustrated with photographs and tables.

REFERENCE: *Asbestos-Cement Pipe* (C105), Portland Cement Association, 1967.

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TABLE 7. **ASBESTOS-CEMENT PIPE**

Characteristics	Applicability to performance	Principal advantages
Smooth surface	Asbestos-cement pipe's roughness flow coefficient, Manning $n = 0.010$, is recognized by engineers as approaching an ideal smooth-flow surface.	High, efficient flow capacity
Corrosion resistance	A long service life is assured because the pipe will not tuberculate or rust and reduce flow capacity; resists both corrosive natural waters and active soils; and is a nonconductor.	Maintained flow capacity; immunity to electrolysis; ensured service life
Strength	Wide range of pipe strengths allows the designer flexibility, with assurance of adequate safety factor. Each pipe and coupling is tested to pressures well above working stresses.	Maintained strength; no costly overdesign
Adaptable couplings	Available for every purpose, couplings are designed to withstand internal and external loads assuring maximum tightness and reasonable flexibility. Joint construction permits rapid installation, laying around curves, absorption of ground settlement, and maintenance of tightness.	Tightness and easy assembly
Construction workability	The light weight, long lengths, and adaptable couplings permit rapid, economical installations. The pipe is easily field-cut with normal construction tools.	Easy handling and assembly
Durability	Corrosion resistance and maintained strength are inherent in the asbestos-cement combination. Proven service records attest to satisfactory performance even in adverse soil-water-gas installations.	Long service life
Dependable performance	The inherent properties of asbestos-cement pipe make it ideally suited for water supply systems, waste water lines, storm drains, irrigation, mine lines, oil and brine lines, underdrains, gas vents, plumbing vents, air ducts, and conduits.	Many and varied uses

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