

DESIGN MANUAL

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JOHNS-MANVILLE TRANSITE®
TRANSMISSION PIPE 18"-36"

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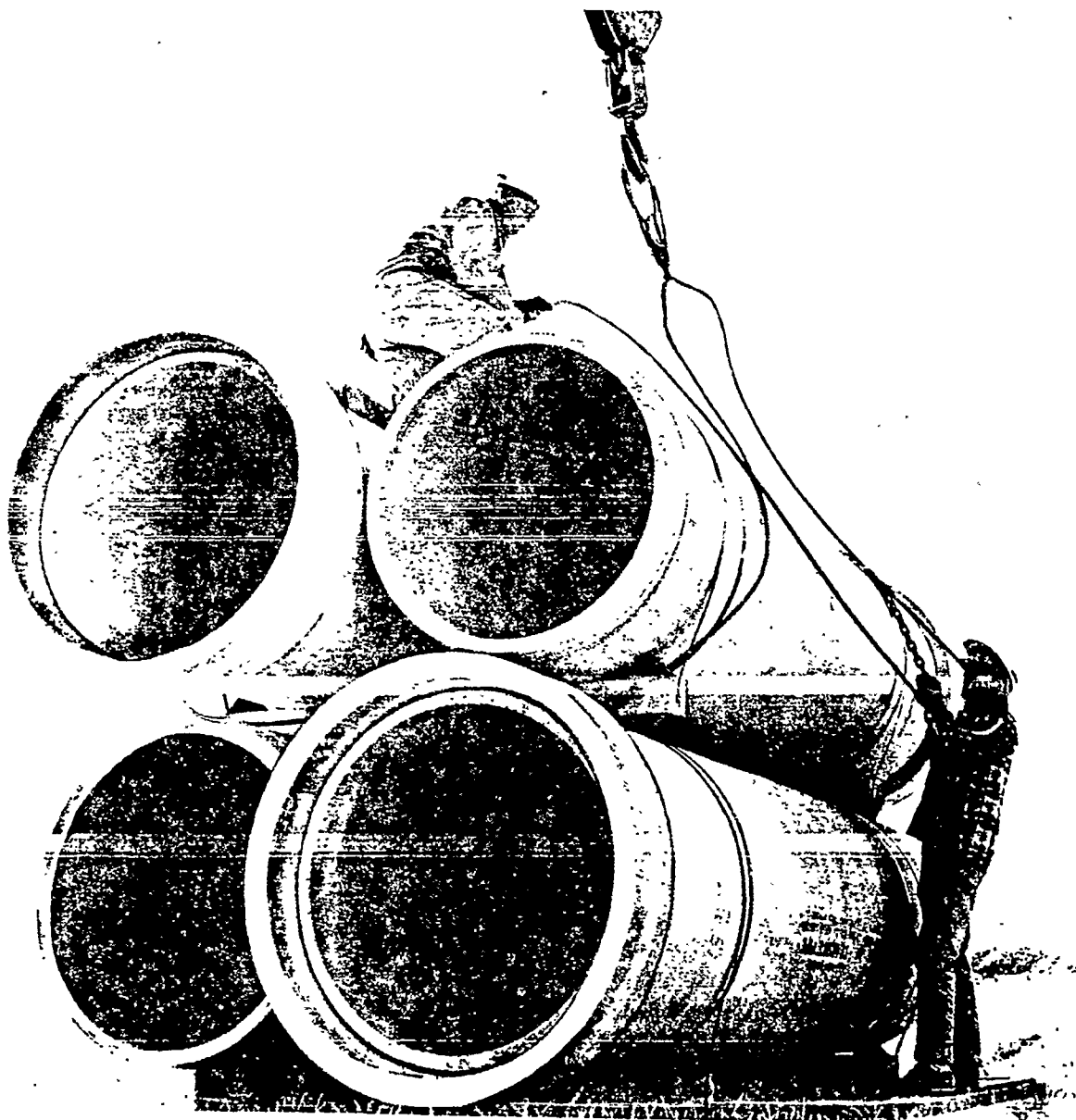
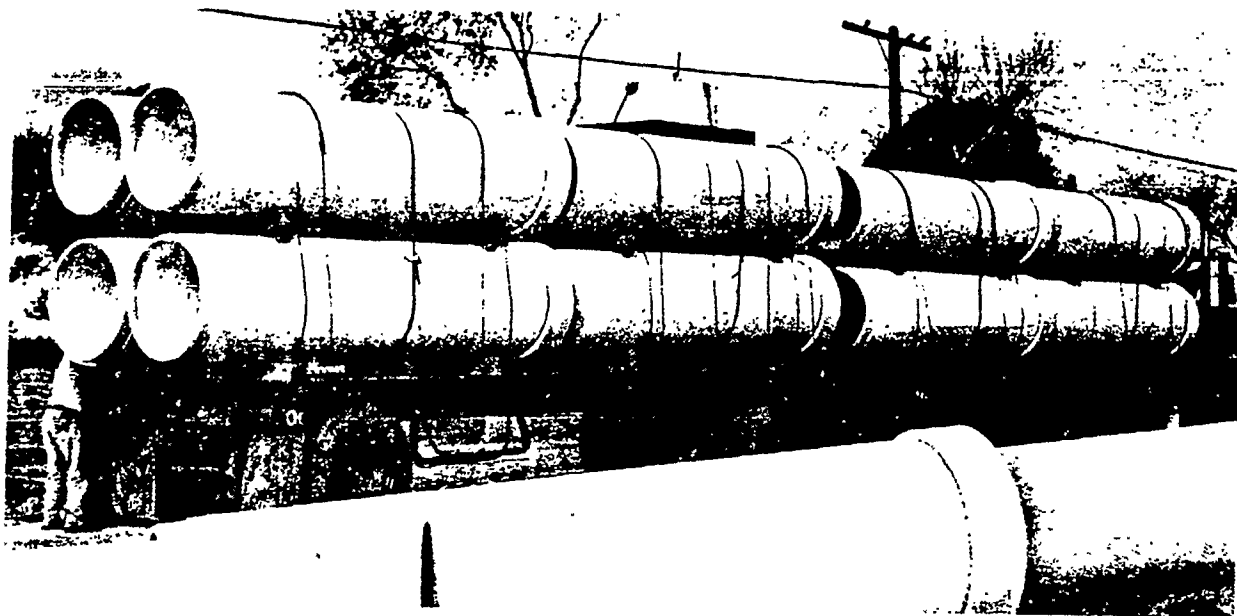
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PREFACE

Johns-Manville has recognized the need of water works and other industries for large asbestos-cement pipes in a wide range of strength classifications. With a wide selection of pipes to choose from, maximum economies can be obtained by the design engineer through thorough analysis and selection of pipe strengths that closely match engineering requirements for each section of his pipeline.

To meet this need for economy in material and efficiency in long-term service, TRANSITE Transmission Pipe was developed. It is currently supplied in six strength classifications and eight sizes, from 18" through 36".

This manual presents the latest techniques in design and selection of TRANSITE Transmission Pipe for transmission and feeder mains, pressure sewer lines, industrial process lines, et cetera. It has been prepared to provide the designer with the engineering data needed to readily select the most economical pipe with adequate strength for a particular service which is compatible with the best engineering practices.



SECTION 1

Introduction to Design Manual for "TRANSITE" TRANSMISSION PIPE

DEFINITIONS AND ECONOMIC CONSIDERATIONS

The main function of a piping system is to transport a fluid such as water from one point to another. Piping systems can vary from simple runs to grids which are complex in nature. In designing a pipe line, the designer must examine all parameters involved in his particular system.

The design concept outlined in this manual offers the designer more selectivity in meeting his engineering requirement while at the same time balancing it against economics of the installed pipeline. This concept has evolved from the long experience that Johns-Manville, numerous engineers and users have had with asbestos cement pipe in many different services.

The design concept involves taking a closer look at the various external and internal loads to which a pipeline is subjected. The engineer is then able to design the pipeline and select the classification of pipe that best fits his needs.

Because Johns-Manville offers a broad range of strength classifications and sizes in its line of TRANSITE Transmission Pipe the designer has the freedom of selection necessary to provide the most efficient system in relation to engineering requirements and installed costs.

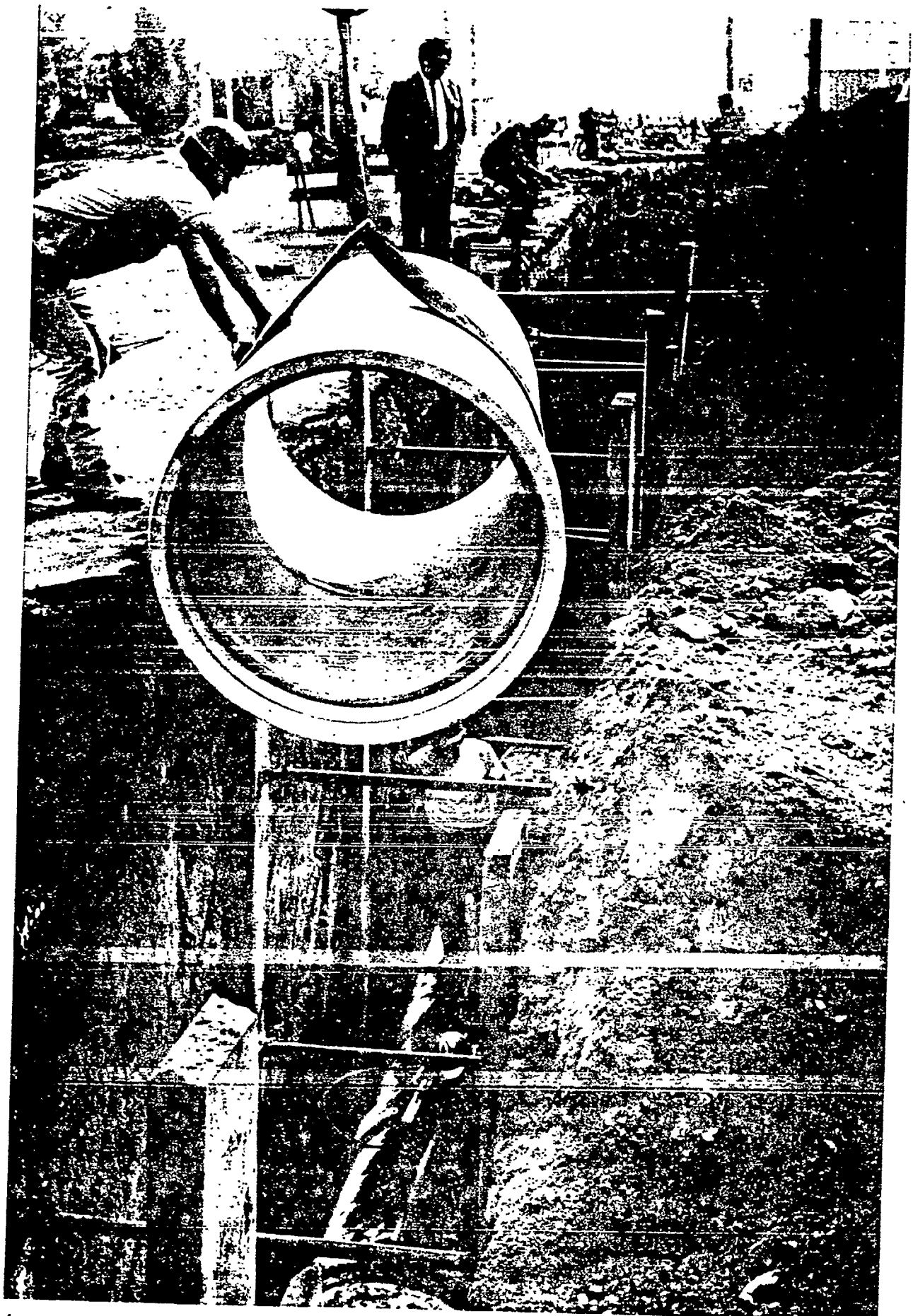
A further discussion of TRANSITE Transmission

Pipe specific benefits, manufacture, and properties is presented in Appendix A.

OBJECTIVES OF DESIGN MANUAL

Some of the information needed for the design of a piping system includes the necessary hydraulic properties of the system, the structural requirements, the service environment, materials to be used with alternates, and the technical data necessary for proper material and equipment selection. All of these facts are evaluated and the system design brought to the proper balance between requirements and cost. The desire of the piping system owner for a safe, maintenance free, and efficient system at a minimum cost may then be satisfied.

This manual has been prepared to be of maximum assistance to the design engineer for the efficient selection of TRANSITE Transmission Pipe. It contains basic and yet convenient design procedures with suggested safety factors for the rapid selection of the most economical pipe to adequately meet the job requirements. Sufficient detail is presented in the text and appendixes such that the engineer may verify each step in the design procedure. Sample design problems are included for demonstration. Also included in the manual are engineering and dimensional data, recommended installation procedures, material specifications and installation specifications.



SECTION 2

Design and Selection Practices for "TRANSITE" TRANSMISSION PIPE

The two major design factors that form the basis for transmission pipe selection are pipe diameter and pipe strength. These factors are by no means independent, but for convenience they will be considered separately.

A. PIPE DIAMETER SELECTION

To determine the required diameter of a specific pipe in a system, information relating to volume of fluid flowing, velocity limitations, friction factor of pipe, and ground profile must be available. Material and pumping costs are also factors which effect the selection from an economic standpoint. The various factors are studied, judged in relation to one another and the size of pipe selected based on the engineers evaluation of all the factors involved. Influencing the designer's decision would, of course, be the results of studies on pumping costs vs. pipe diameter, future growth in demand and cost of surge control equipment if required.

Appendix B (Figure 2) presents a nomograph of the Hazen-Williams formula for assistance in determining the pipe diameter, head loss, and flow velocity for various quantities of flow. In piping systems which have long runs with relatively few fittings and accessories, the recommended value of C is 150. A second nomograph in Appendix B (Figure 1) includes a relationship for determining horsepower required to overcome friction head loss for any given value of "C". The yearly power cost to compensate for friction loss of head can be determined by converting horsepower required to kilowatt hours per year and multiplying by the power cost per KWH. The conversion factor is shown on the nomograph.

Example problems are also shown in the Appendix for illustration.

B. PIPE STRENGTH SELECTION

After the pipe diameter has been established, the designer must determine the strength of pipe by next evaluating internal and external loads on the pipe. Following is a listing of these loads to be considered. Separate sections are presented in this manual showing methods to determine the actual value of these loads in a convenient manner according to accepted engineering practice. The combined loading principle which employs these computed internal and external loads is described. The method to most easily apply this principle for the rapid and accurate selection of pipe strength for given service conditions is presented on a step by step basis with illustrative examples.

LOADS ON TRANSMISSION PIPE AND FACTORS AFFECTING LOADS

1. External loads

a. Earth loads

1. Depth of cover
2. Width of trench
3. Weight of soil
4. Type of soil
5. Bedding condition

b. Live load

1. Magnitude of load and type of load
2. Depth of cover
3. Impact factor
4. Bedding factor

2. Internal loads

a. Operating pressure

b. Hydraulic gradient

c. Surge

1. Velocity
2. Pump characteristics
3. Surge control devices
4. Pipe material, wall thickness, diameter

COMBINED LOADING PRINCIPLE

At any given moment a pipe in service is generally subjected to a combination of internal and external loads. Various combinations of earth load, live load, operating pressure and water hammer can be determined within reasonable limits in a well designed system. The pipe selected for a particular job must stand up to the combinations of steady and transient loads as calculated for that job. Adequate safety factors should be incorporated as consistent with known service conditions and the ability to control installation and transient load conditions.

The maximum tensile or compressive stresses induced in the pipe wall by internal pressure and external loads have been found to be additive according to widely accepted rigid conduit theory and testing. Consequently, the magnitude of internal pressure that can be safely resisted by a rigid pipe such as TRANSITE will vary inversely with the magnitude of external loading applied simultaneously.

It has been found through combined hydrostatic and crush loading tests to ultimate pipe failure that the behavior of TRANSITE Transmission Pipe may be shown by the Schlick formula which states:

$$w = W \sqrt{\frac{P - p}{P}}$$

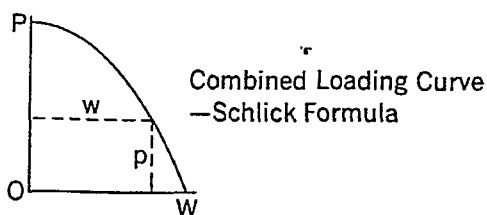
Where: P = the internal hydrostatic design pressure for the pipe when no external load exists—psi.

W = the external crushing design load for the pipe (3-edge bearing test) when no internal pressure exists—lbs/ft of pipe.

p = the internal hydrostatic pressure for that pipe when an external crushing load (w) is acting simultaneously—psi.

w = external crushing load for the pipe when an internal pressure (p) is also acting on the pipe—lbs/ft of pipe.

This may be interpreted graphically by the following:



Each of the factors that contribute to the external or internal loading of the pipe are considered separately in the next section.



EXTERNAL LOADING

Earth Loads

The earth in the trench back-fill produces a crush load on the pipe. Formulas developed by Marston have been shown to be reliable for computation of these loads.

There are two general forms of the Marston formula that apply individually depending on trench width and depth conditions. Appendix C presents these formulas and their method of use. The first formula shown in Appendix C applies to what is generally referred to as the "trench load" condition and usually occurs when the trench width is less than two to three times the conduit width, depending on the conduit size and depth of trench. The assumption is made that friction between the back-fill and trench walls will affect the load on the pipe. The second formula in Appendix C applies to wide trenches and is referred to as the "positive projecting conduit condition." The trench walls are assumed to have no effect on the load on the pipe in wide trenches. The earth load computed under this condition is theoretically the maximum load on the pipe for a given depth of cover. Appendix C illustrates use of these formulas with a sample problem.

For the designer's convenience, computations have been made for the earth load on each size of pipe from 18" to 36". Various trench widths have been used with earth covers from two to twenty feet. These charts are also shown in Appendix C. Weight of earth was taken as 120 lbs/ft³ for the calculations. Corrections for other earth weights may be made by simple direct proportion.

Live Loads

Live loads are usually caused by a wheel from a vehicle passing over the trench backfill. The loads occur over a relatively small bearing area on the ground and, therefore, may be considered as concentrated. The load from the wheel that actually reaches the level of the pipe decreases rapidly with depth of cover.

The accepted formula used to compute the magnitude of this load is presented in Appendix D.

The formula includes a factor for impact which may be caused by the wheel hitting a bump directly over the pipe. The factor "F" to be used for impact decreases with depth of cover. In accordance with AASHTO recommendations no impact factor is used for depths of cover greater than three feet. (See Appendix "D" for depths of cover of one to three feet.)

As recognized, the impact factor rapidly diminishes with depth because of the effective dampening characteristics of the earth.

Crush Loads—Characteristics of TRANSITE Transmission Pipe

The crushing strength of TRANSITE Pipe is dependent upon its wall thickness and the inherent strength of asbestos-cement as a structural material. The test used to establish the crushing strength of TRANSITE Pipe is found in ASTM C500, "Standard Methods of Testing Asbestos-

Cement Pipe." The amount of backfill load a given pipe will withstand is further increased from the test strength values, however, due to the load distribution effect of the bedding under and around the pipe. To determine the supporting strength of the pipe and bedding system, therefore, the crush strength of the pipe is multiplied by a factor (bedding factor) reflecting the quality of the bedding.

Appendix E presents illustrations of the four bedding conditions in common use. This chart is followed by a table of bedding factors applicable to each bedding condition, i.e. these represent the magnitude of upward adjustment of crush load over the three-edge values.

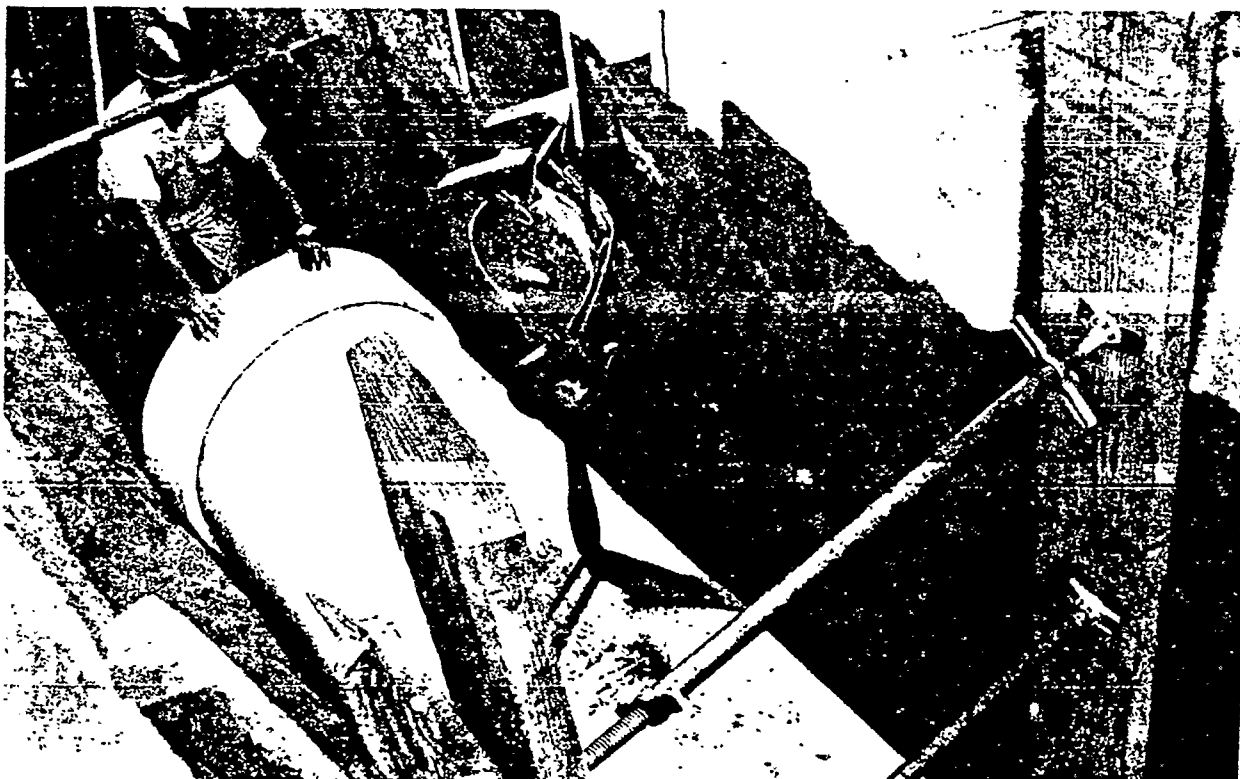
INTERNAL PRESSURE

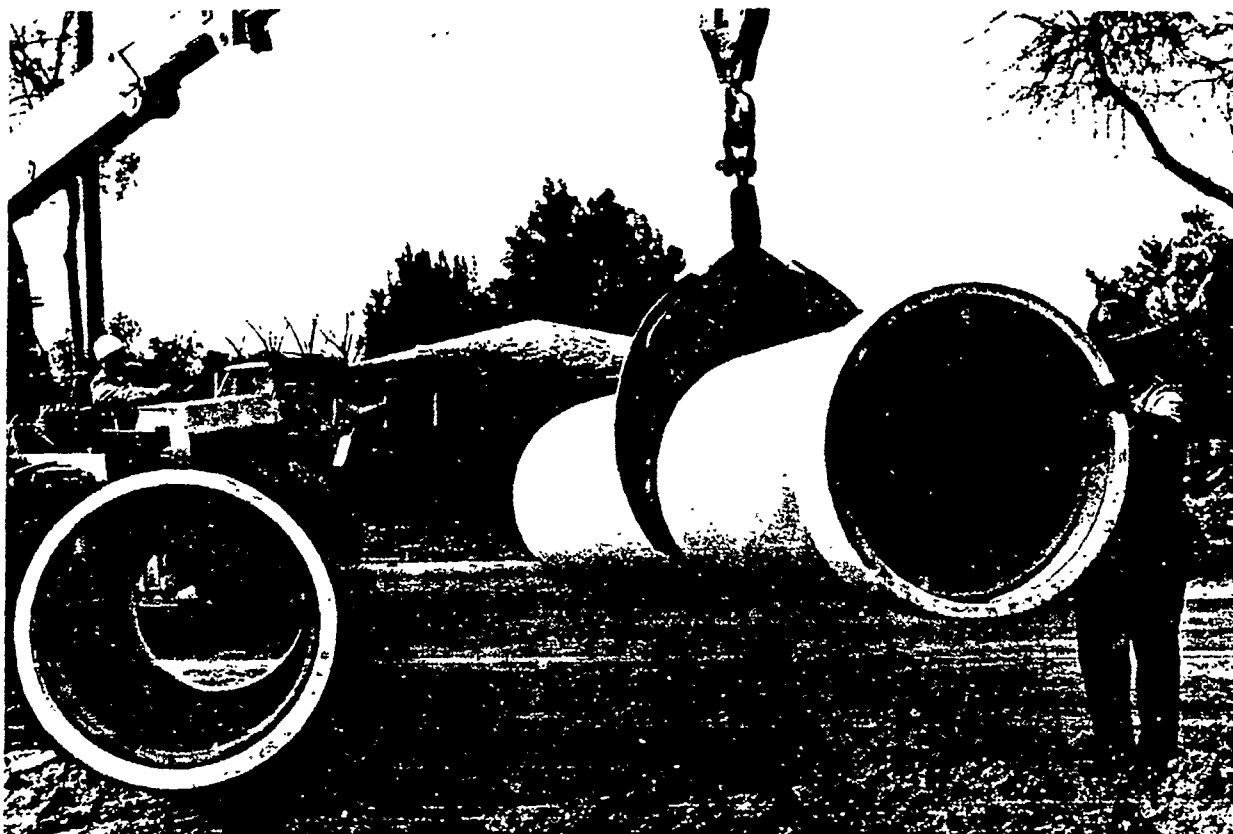
For simplicity in design and selection of TRANSITE Transmission Pipe, the internal pressure may be separated into two categories:

1. Operating Pressure
 2. Water Hammer or Surge
- Each will be determined separately.

1. Operating Pressure

The operating pressure is that pressure which exists under normal or steady conditions of operation. The pressure may be induced by pumps, from gravity such as the head created by a reservoir or elevated water tank, or combination of both pumps and gravity. Under a purely gravity situation, the





pressure in the line at a given point is somewhat higher when there is no flow or conditions are static. Under static conditions the pressure at a given point, measured in feet of head, is equal to the difference in the elevation of that point and the water surface level at the reservoir. Under flowing conditions the pressure at the point under consideration is reduced by the amount of friction and other energy losses resulting from the flow of water from the reservoir to that point. The magnitude of this loss in head may be found by use of the Hazen-William's nomograph in Appendix "B" Figure 2.

2. Water Hammer or Surge

Surge pressures are of a transient nature and are caused by unsteady or changing conditions in the pipeline. The names "water hammer," "surge," or "transient pressure" are often used interchangeably to refer to these pressures of brief duration, but often of considerable magnitude. A variety of conditions may cause surge pressures. These include a valve opening or closing, sudden movement of air in a line, or a pump starting or stopping.

Transient pressures are often a controlling factor in the selection of a pipe strength. For this reason, a pipe system should always be analyzed for surge pressure determinations and the results used in pipe selection.

There are numerous methods for control of surge pressures in the line. Consideration should be given

to use of these devices to limit pressures to an acceptable level. Economics plays a major role in this area. Various designs may have to be balanced depending on the complexity of the system to yield an economical and efficient design.

Appendix F presents a discussion of water hammer with emphasis on how it may be analyzed and methods of control. Although the subject is discussed in some detail and an illustrative problem included involving surge pressure control by timing a valve closure, the subject is too complex to be thoroughly covered in the design manual. It is suggested that control of surge for any transmission system be discussed with surge control equipment manufacturers or consultants in this field.

The effects of surge in a pipeline, however, should not be ignored as possible neglect of this factor may result in severe damage to the system.

Also, because of the number of variables involved in creating water hammer pressures and the ability to regulate their magnitude with proper controls, it is not recommended that fixed water hammer allowances based on pipe diameter or some other single criterion be used.

AIR IN PIPELINES

Air can enter pipelines from several sources and in doing so, can create problems such as reduced ca-

capacity and magnified surge plus other serious operational difficulties. The pipelines should be installed to grade rather than to follow the earth surface, so as to reduce the number of locations where air can accumulate in a line. Care should be taken to insure that all air possible be eliminated from the pipeline both during initial filling of the line and during operation.

Appendix G describes ways air can enter a line and suggests solutions for proper control.

COMBINED LOADING CURVES

As discussed above it has been demonstrated satisfactorily by tests that TRANSITE Transmission Pipe conforms generally to the "Schlick formula" for combined loading. Numerous tests have established values for internal hydrostatic design pressure with no crush load applied (P) and external crush design loads with no internal pressure applied (W) for all diameters and strength classifications. These values represent the end points on the combined loading curves with the intermediate points computed by use of the Schlick formula. (It should be noted that all values used for P and W represent a conservative interpretation of the test data.) The intermediate points on the curve, w and p, are the combinations of crush loading and internal pressure the pipe will withstand when these loads are applied simultaneously.

In Appendix H graphs are presented for each diameter of pipe from 18" through 36". On the graph for each diameter of pipe a combined loading curve is drawn for each strength classification



of that size pipe. The vertical axis represents the internal hydrostatic design pressure (P) and the horizontal axis the external design 3-edge bearing crush load (W). The chart presented before the graphs lists the values of P and W for the strength classifications of each pipe size. The method for selection is outlined in the section on the "Use of Selection Charts" below.

SAFETY FACTORS

Safety factors normally are applied by the engineer to his computed design values of crush and internal pressure to be resisted by the pipe in service. These factors protect against unforeseen loads that may be placed on the line at some time in the future, and for other contingencies such as improper construction. It is the engineers' prerogative to select what safety factors he feels should apply to a given system.

Considerable field experience as well as extensive laboratory work has yielded a wealth of information on the behavior of TRANSITE Pipe. For this reason the following suggestions on minimum safety factors are made for use in selecting TRANSITE Transmission Pipe.

Suggested Safety Factors for use with TRANSITE Transmission Pipe Selection

Type of Load	Safety Factor	
Operating pressure + water	Hydro	Crush
hammer combined with earth load + live load	2.0	1.5

Note that safety factors are applied to both hydro and crush simultaneously in the selection of TRANSITE Pipe since the combined loading principle is applicable. Note also that water hammer and live load, which are both transient load conditions, are considered as acting simultaneously for design purposes here. Since the likelihood of both occurring at the same time is very small, an additional conservative element is introduced into the design.

USE OF SELECTION CHARTS FOR ECONOMICAL DESIGN

After all loads on the pipe have been computed (Operating pressure, water hammer, earth load, live load) select the most economical strength of pipe to meet the service conditions. Use the applicable procedure depending on the safety factors used.

A. Selection procedure using safety factors as suggested by Johns-Manville

1. Add operating pressure and water hammer (OP + WH) (See Appendix F).
2. Add earth load and live load (EL + LL) from Appendixes C & D.

3. Enter the combined loading graph in Appendix H for the appropriate diameter of pipe. Plot as one point the values from 1 and 2. When using the lefthand scales, be sure to multiply the operating pressure and water hammer by the Johns-Manville suggested safety factor of 2.0. When using the bottom scale be sure to multiply the earth load plus live load by the Johns-Manville suggested safety factor of 1.5 and divide it by the bedding factor.

4. The point will lie between the curves for two pipe strengths. Select the higher strength of the two. This represents the most economical selection consistent with engineering requirements.

B. Selection procedure using safety factors as selected by the designer.

1. Add operating pressure and water hammer (OP + WH) (See Appendix F).
2. Add earth load and live load (EL + LL) from Appendixes C & D.
3. Multiply (OP + WH) times safety factor in hydro.
4. Multiply (EL + LL) times safety factor in crush and divide by the bedding factor to be employed. This compensates for the fact that W on the graph was established on the basis of three-edge bearing tests.
5. Enter the combined loading graph in Appendix H for the appropriate diameter of pipe. Plot as one point the values obtained from steps 3 and 4.
6. The point will lie between the curves for two pipe strengths. Select the higher strength of the two.

It is recognized that additional design procedures may be employed by using various combinations of the external load and internal pressure. Selections may be made, however, by essentially following the above procedure and varying the load combinations as described.

PIPE AND FITTINGS

Appendix J presents detailed dimensional data on pipe and couplings in sizes 18" and larger in all the available strength classifications. Weights of pipe are also included.

Details and data on steel and cast iron fittings can be obtained from the applicable AWWA or other standards.

If any additional information or classification is desired, please contact your J-M representative or Customer Service Center.

SYSTEM SPECIFICATIONS

As a convenience and guide to the engineer, system specifications have been prepared and are included in Appendix K.

These are:

1. Material Specifications for TRANSITE Transmission Pipe.
2. Installation Specifications for TRANSITE Transmission Pipe.

INSTALLATION

Installation and construction techniques are presented in detail in the "Transite Transmission Pipe Installation Guide" published by Johns-Manville. This booklet is available to contractors and others concerned with the installation of TRANSITE Pipe. Supplementary information follows.

THRUST CONTROL

Thrust control is a critical factor in the design of pressure lines. Drawings of general types of thrust control that can be employed where particular conditions are encountered are presented in Appendix L. Combinations of these arrangements may be utilized where multiple fittings occur or where standard methods cannot be applied.

Thrust control is dependent on pipe size, the type of soil, and the maximum anticipated pressure (considering surge and test pressures) in the pipeline.

APPENDIX A

TRANSITE Transmission Pipe—Manufacture and Properties

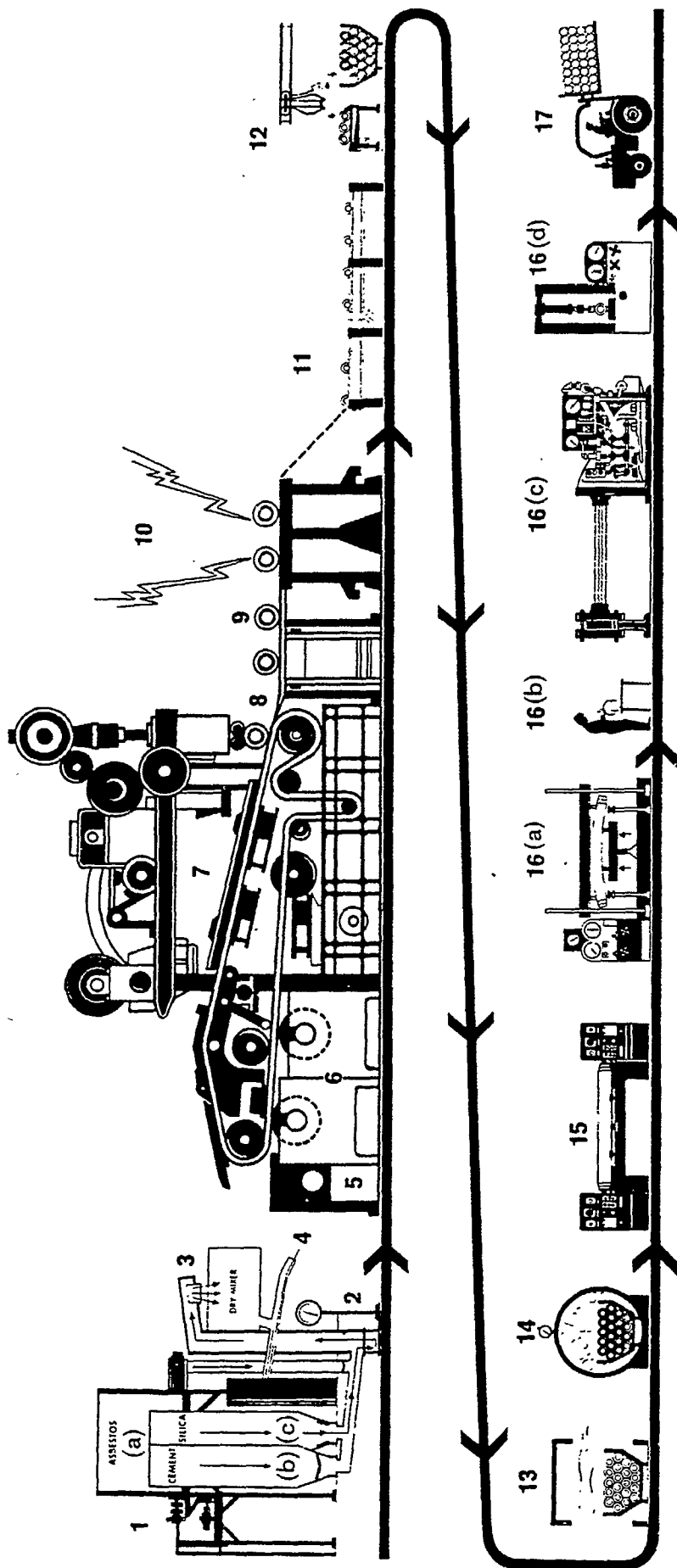
Johns-Manville TRANSITE Pipe is an asbestos-cement product. It is composed of an intimate mixture of Portland cement, silica and asbestos fiber. The material is completely free from organic or metallic substances.

Figure 1 presents a flow chart depicting the method of manufacture of TRANSITE pipe. The pipe is formed under pressure on a steel mandrel creating a dense wall with a smooth interior surface. Final curing of the product is done in an autoclave employing high pressure steam (100 psi) for dimensional stability and chemical stability.

The properties of TRANSITE Transmission Pipe that make it particularly advantageous include the following:

- a. TRANSITE is an asbestos-fibre-reinforced product. The asbestos fibres used have a tensile strength as high as 400,000 psi and the fibres are oriented in the material in such a way as to utilize their high tensile properties for maximum reinforcement and stress resistance. The high strength of TRANSITE may be demonstrated by examining the hydrostatic and crush strengths of each size and strength of pipe. A chart with these values is shown in Appendix H. Continuous plant testing assures the maintenance of these high values.
- b. The wide range of strengths available within each pipe size has been graduated so that maximum economies can be achieved by selection of the proper pipe to do the job.
- c. The high corrosion and chemical resistance of TRANSITE pipe make it highly resistant to corrosive soils and waters. This gives assurance of a long useful life with high maintained flow.
- d. The Ring-Tite joint system with rubber rings assures a tight system with no leakage. Machining to close tolerance at the factory together with rigid quality control assures an installation that in addition to being tight goes together fast. Rubber ring joints also add flexibility to the line which can be of great value under conditions of shifting soils and vibrations.
- e. The initial Hazen-Williams "C" factor of 150 for TRANSITE Lines which have relatively few fittings and accessories, may be depended upon by the designer to be maintained over the entire life of the pipe. Therefore, initial efficient designs with TRANSITE do not have to be altered because of consideration of any change in the "C" factor by interior surface roughing. TRANSITE maintains a smooth interior surface providing lower pumping costs.





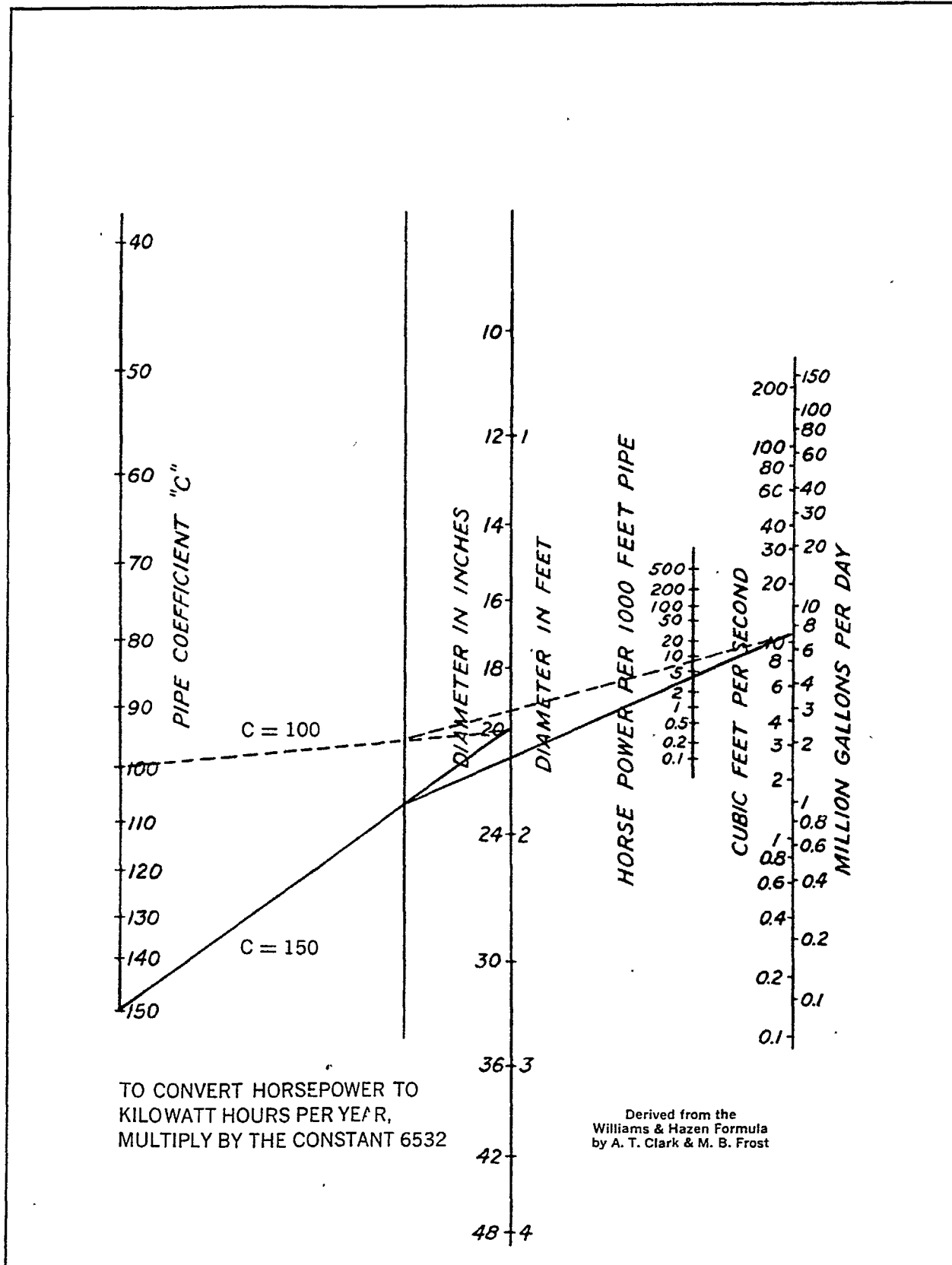
FLOW CHART OF TRANSITE PIPE MANUFACTURE

1. Production line bins—raw materials enter the line as follows:
 - (a) asbestos—from the willow where the fiber is separated into individual strands and thoroughly mixed
 - (b) cement—directly from receiving hoppers
 - (c) silica—from grinding mill
2. Electronic Scales—for precise weighing; accurate control for uniform results
3. Dry Mixer—blends raw materials thoroughly
4. Conveying Trough—water carries stock to wet mix vat
5. Wet Mix Vat—thorough dispersion of reinforcing fibers
6. Screen Cylinder Mold—picks up slurry and deposits on moving felt
7. Vacuum Box—excess water removed
8. Felt deposits stock on Mandrel—wall thickness built up under pressure to proper size

9. Mandrel (with pipe)—removed from machine; next mandrel positioned
10. Electrolytic Loosener—frees pipe from mandrel; prevents distortion
11. Slow-down Conveyor—provides pre-cure time; initial set
12. Mandrels—removed and pipe stencilled for identification
13. Air Cure Room—strict control of time, temperature and humidity
14. Autoclaves—high pressure steam curing imparts maximum strength and excellent chemical stability
15. Lathes—trim and machine ends to exact dimensions
16. Testing Equipment—checks for adherence to rigid specifications
 - (a) flexure testing machine
 - (b) inspection
 - (c) hydrostatic tester
 - (d) crush tester (laboratory)
17. Materials Handling Equipment—transfers pipe to shipping area

APPENDIX B

Fig. 1 FLOW POWERGRAPH



ILLUSTRATIVE PROBLEMS ON PIPE DIAMETER SELECTION

PROBLEM 1

The minimum elevation of the surface of a reservoir is 198 feet. A TRANSITE transmission line ($C = 150$) is to carry water by gravity to a city distribution system, a distance of 5 miles. The pressure at the entrance to the distribution system is to be a minimum of 75 psi. Design flow is 6000 gallons per minute. Determine the size of pipe required and the velocity of design flow.

Solution:

Head From Reservoir	198 ft.
Head Delivered to Distribution System	
2.31×75	174 ft.
Allowable Loss of Head	24 ft.

Length of Line = $5 \times 5280 = 26,400$ ft.
 Allowable loss of head per 1000 ft. ($C = 150$) = $24/26.4 = 0.91$ ft.

Enter nomograph in Figure 2 on either top or bottom horizontal axis at 0.91 ft. loss in head per 1000 ft. Go vertically to intersection of 6000 gal./min. This lies between 27" and 30" diameter pipe. Therefore use 30". This will deliver about 6500 gpm at a velocity of about 3.4 ft. per second.

PROBLEM 2

Water is to be pumped from one reservoir to another by means of a TRANSITE transmission line 50,000 ft. long. The lower reservoir is at elevation 100 ft. and the upper at 250 ft. Design flow is to be 5000 gpm and the velocity is not to exceed $5\frac{1}{2}$ ft/sec. Determine a) the size of pipe required, b) the maximum head at the pump, c) the

horsepower and annual power cost required to overcome friction only (not elevation difference) and d) the annual power cost to overcome friction in the line if $C = 100$ (assume power cost = \$.02 per kwh).

Solution:

- a. Enter nomograph in Figure 2 at 5000 gal/min. Proceed to intersection at $5\frac{1}{2}$ ft/sec. This falls between 18" and 20" diameter pipe. Use 20" pipe. This will give a velocity of about 5.3 ft/sec. at design flow and head loss of 3.3 ft/1000 ft. for $C = 150$.
- b. Elevation difference = $250 - 100 = 150$ feet
 Friction loss = $50 \times 3.3 = 165$ feet
 Max. head at the pump = 315 feet
- c. Horsepower and power cost to overcome friction: Use nomograph in Figure 1—5000 gpm = 7,200,000 gal/day. Enter nomograph at $C = 150$, 20" diameter and 7,200,000 gal/day. Find horsepower/1000 ft. as indicated. This is 3.4 HP/1000 ft., converting to Kwh = $3.4 \text{ ft.} \times 6532 = 22,210 \text{ Kwh/year/1000 ft.}$
 $22,210 \times \$0.02 = \$444.20/\text{year/1000 ft.}$
 Total power cost/year = $\$444.20 \times 50 = \$22,210.00/\text{year for } C = 150.$
- d. Repeat procedure for $C = 100$, 20" diameter and 7,200,000 gal/day
 horsepower/1000 ft. = 8. HP/1000 ft.
 $8.0 \times 6532 = 52,200 \text{ Kwh/yr./1000'}$
 $52,200 \times \$0.02 = \$1,044.00/\text{yr./1000'}$
 Total power cost for 1 year = $\$1,044.00 \times 50 = \$52,200.00/\text{yr. for } C = 100.$



PER THOUSAND FEET OF LENGTH

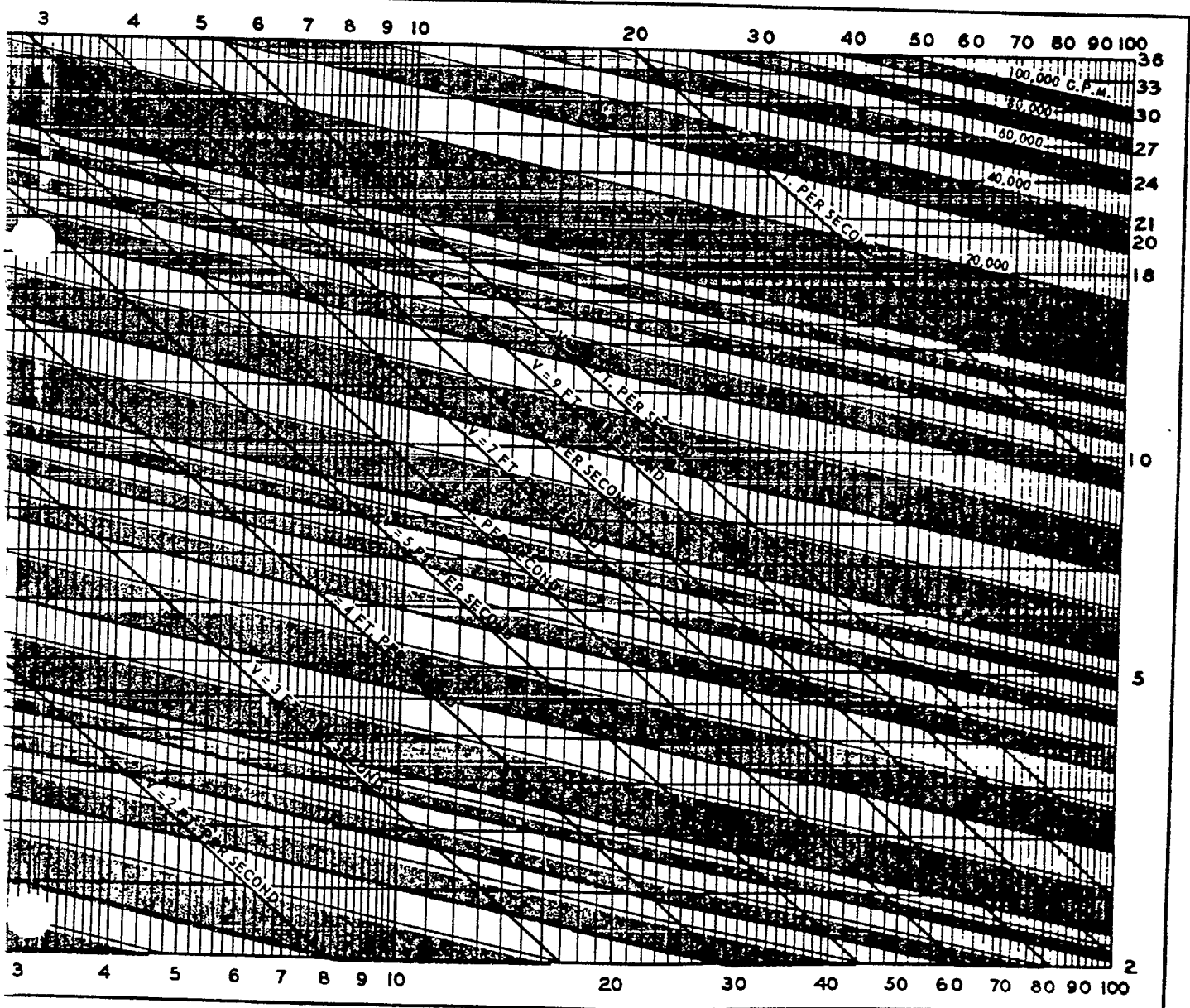


Fig. 2 FRICTION LOSS OF HEAD CHART

COEFFICIENT OF FLOW $C = 150$
DERIVED FROM THE WILLIAMS AND HAZEN FORMULA — $V = 1.318CR^{.63}$

In transmission piping systems which have long runs with relatively few fittings and accessories, Transite Transmission Pipe has a coefficient of $C = 150$. Because of Transite's asbestos-cement composition, this initial high flow capacity cannot be reduced by tuberculating water — the chief cause of loss in carrying capacity. This helps maintain the carrying capacity provided for future requirements and is an important factor in minimizing pumping costs.

Note: Loss of Head values derived from this chart are for coefficient of flow $C = 150$. They may be converted to loss of head for other coefficients of flow by means of the following multiplying factors:

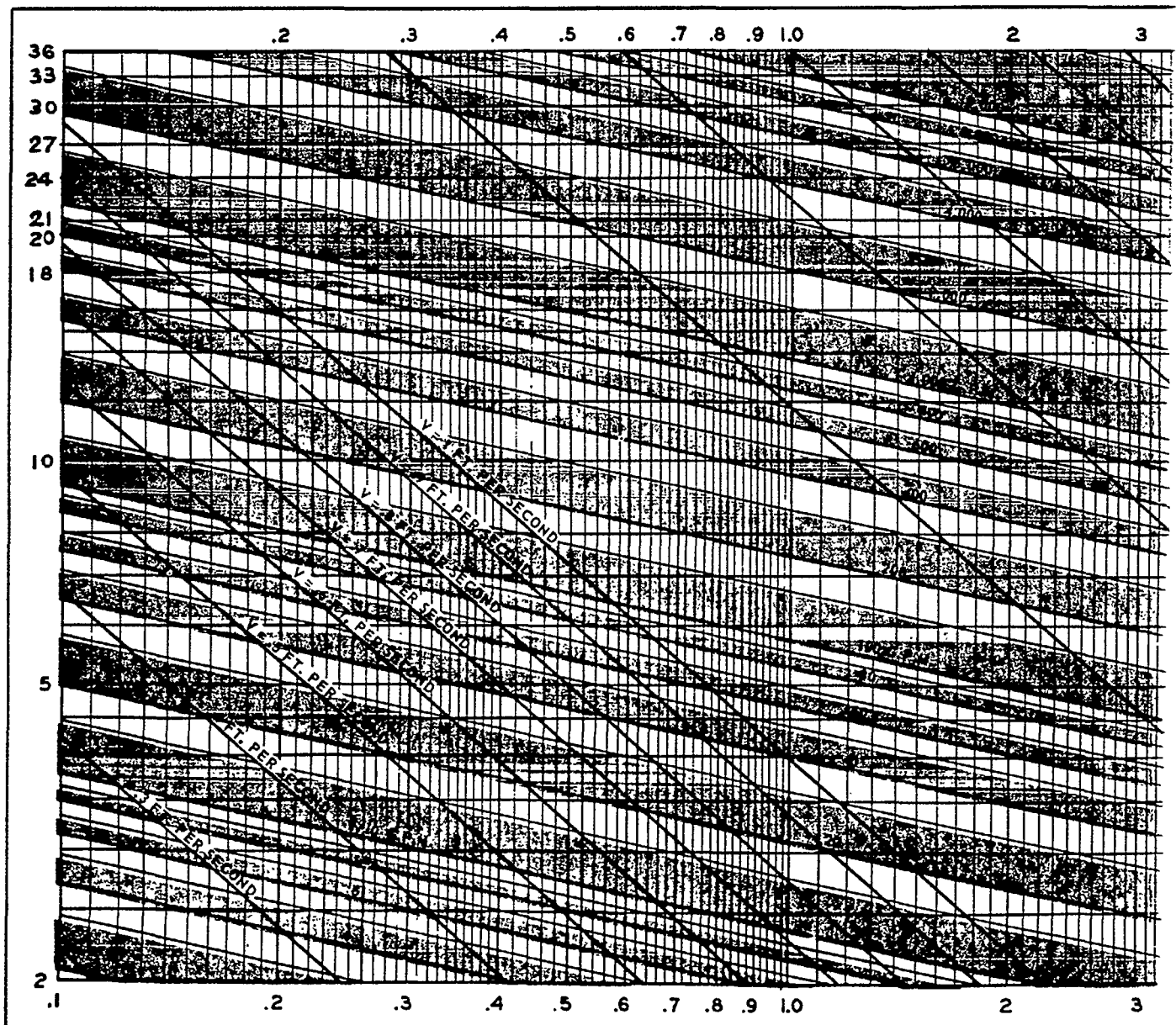
1.13 for $C = 140$	1.77 for $C = 110$	2.58 for $C = 90$
1.30 for $C = 130$	2.12 for $C = 100$	3.22 for $C = 80$
1.51 for $C = 120$		5.46 for $C = 60$

Note: Diameters derived from this chart are for coefficient of flow $C = 150$. These may be converted to diameters for other coefficients of flow by means of the following multiplying factors:

1.03 for $C = 140$	1.13 for $C = 110$	1.22 for $C = 90$
1.07 for $C = 130$	1.18 for $C = 100$	1.30 for $C = 80$
1.10 for $C = 120$		1.41 for $C = 60$

LOSS OF HEAD IN FEET PER 100 FEET

PIPE DIAMETER, INCHES



CONVERSION FACTORS

Multiply _____	By _____	To Obtain _____
Acre—feet	325,851	Gallons
Barrels (42 gallons) per day	.02917	Gallons per minute
Barrels (31 gallons) per day	.02153	Gallons per minute
Barrels (45 gallons) per day	.03125	Gallons per minute
Cubic feet of water	7.48052	Gallons
Cubic feet per second	448.831	Gallons per minute
Cubic feet per second	0.64617	Million gallons per Day
Feet of Water	62.43	Pounds per square foot
Feet of Water	0.4335	Pounds per square inch
Gallons of Water	8.3453	Pounds of water
Gallons of Water	231	Cubic inches
Gallons per minute	2.228×10^{-3}	Cubic feet per sec.
Horsepower	0.7457	Kilowatts
Horsepower	6532	Kilowatt hours per year
Million Gallons per day	694.4	Gallons per minute
Pounds per square inch	2.31	Feet of water



APPENDIX C

THE MARSTON FORMULAS FOR COMPUTATION OF EARTH LOADS ON A CONDUIT

1. $W_d = C_d w (B_d)^2$

Trench condition (trench width usually less than 2 to 3 times conduit width)

2. $W_c = C_c w (B_c)^2$

Projecting conduit condition (where trench width greater than or equal to "transition width")

in which:

"Transition Width"—That width corresponding to the load computed by the trench formula equal to the maximum earth load as calculated by the projecting conduit equation. That is, for the same depth of cover, trenches wider than the "transition width" will not yield a greater load on the pipe than the projecting conduit load.

W_c and W_d = loads on the pipe in pounds per foot

C_c and C_d = load coefficients dependent on a variety of variables such as height of backfill, width of conduit and/or trench and soil characteristics.*

(See Chart below for C_d determination.)

$$C_c = 1.892 \frac{(H)}{B_c} - 0.96$$

w = weight of soil in pounds per cubic foot

B_c = width of the conduit

B_d = width of the trench

H = Height of fill above top of pipe

*For earth load charts the following conditions and constants were used:

$r_{sd}p = 0.70$, which is an average condition for "projecting conduit" loads.

where:

p = projection ratio.

r_{sd} = settlement ratio.

$ku = 0.1924$ conservative for "projecting conduit condition."

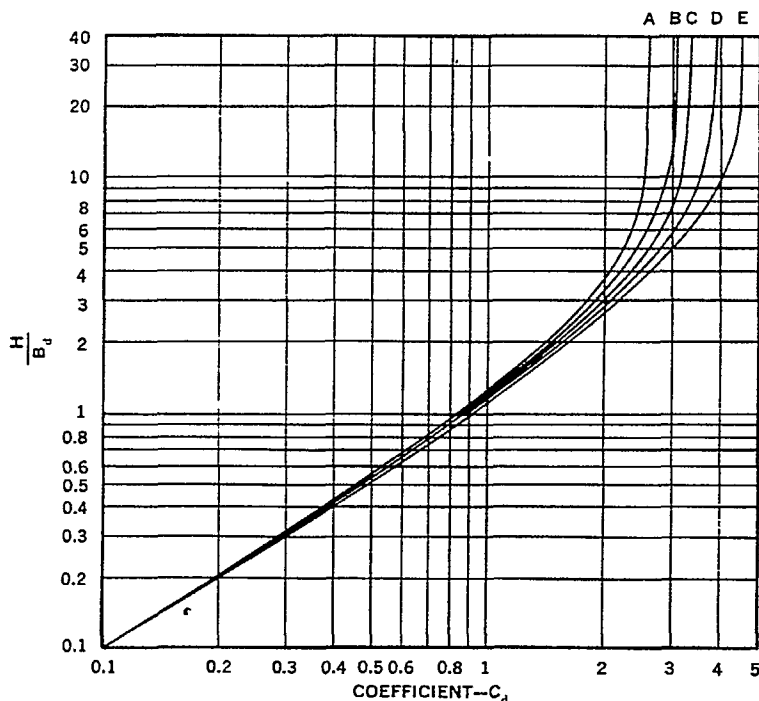
$ku = 0.1300$ conservative for "trench condition"

where:

k = Rankine's ratio of lateral earth pressure to vertical pressure.

u = coefficient of backfill internal friction.

$w = 120 \text{ lbs/ft}^3$



Graph for Determining C_d Coefficients

Each of the above curves represent C_d values for ku and ku' . A represents 0.1924 for granular materials without cohesion; B is 0.165 maximum for sand and gravel; C is 0.150 maximum for saturated

top soil; D, 0.13 maximum for ordinary clay; and E, 0.110 maximum for saturated clay. The symbol u' , is the coefficient of friction between the backfill material and the sides of the ditch.

ILLUSTRATIVE PROBLEMS

An 18" TRANSITE Transmission Pipe is to be installed in a 3 ft. wide trench under 8 feet of cover. The backfill is ordinary clay with a weight of 120 pcf. Determine the earth load on the pipe.

Solution:

The load must be computed 2 ways using the Marston formulas for the trench condition and that for the projecting conduit condition. The engineer, knowing the job conditions and degree of inspection, should decide which load applies.

a. trench condition $W_d = C_d w (B_d)^2$

obtain C_d from graph using curve D and

$$\frac{H}{B_d} = \frac{8}{3} = 2.7$$

$$C_d = 1.9$$

$$W_d = (1.9) (120) (3)^2 = 2100 \text{ lbs/ft}$$

b. projecting conduit condition $W_e = C_e w (B_e)^2$

where $B_e = \text{O.D. 18" pipe} = 1.7 \text{ ft.}$

$$C_e = 1.892 \frac{H}{B_e} - 0.96 = 1.892 \frac{8}{1.7} - 0.96 = 8$$

$$W_e = (8) (120) (1.7)^2 = 2800 \text{ lbs/ft}$$

EARTH LOADS (LBS/LIN FT)

Weight of earth taken equals 120 lbs. per cubic foot.

Correction for other earth weights may be made by simple direct proportions.

BOLD FIGURES INDICATE MAXIMUM EARTH LOAD FOR DEPTH OF TRENCH

Pipe Size 18" I.D.

TRENCH COVER	TRENCH WIDTH									TRANSITION WIDTH
	2'6"	2'9"	3'0"	3'3"	3'6"	4'0"	4'6"	5'0"	5'6"	
2'	490									2'5"
2'6"	640	640								2'8"
3'	810	835								2'10"
4'	1000	1110	1240							3'1"
5'	1200	1320	1450	1610	1640					3'5"
6'	1350	1520	1700	1865	2050					3'8"
7'	1500	1690	1900	2090	2300					3'10"
8'	1600	1850	2100	2320	2525	2825				4'0"
9'	1725	2000	2250	2510	2750	3230				4'1"
10'	1850	2120	2400	2725	2950	3550	3635			4'3"
12'	2050	2360	2675	3020	3300	4000	4440			4'5"
14'	2200	2570	2900	3280	3600	4400	5220			4'7"
16'	2300	2720	3100	3515	3900	4800	5640	6040		4'9"
18'	2400	2840	3275	3720	4150	5100	6040	6830		5'0"
20'	2500	3000	3400	3995	4350	5350	6400	7450	7620	5'2"

Pipe Size 20" I.D.

TRENCH COVER	TRENCH WIDTH									TRANSITION WIDTH
	2'9"	3'0"	3'3"	3'6"	3'9"	4'0"	4'6"	5'0"	5'6"	
2'	545									2'8"
2'6"	705									2'10"
3'	870	890								3'0"
4'	1110	1250	1330							3'4"
5'	1320	1450	1610	1750	1770					3'8"
6'	1520	1700	1865	2050	2210	2220				3'11"
7'	1690	1900	2090	2300	2515	2655				4'1"
8'	1850	2100	2320	2525	2765	3000	3095			4'3"
9'	2000	2250	2510	2750	3040	3300	3545			4'5"
10'	2120	2400	2725	2950	3240	3550	3980			4'6"
12'	2360	2675	3020	3300	3660	4000	4660	4810		4'10"
14'	2570	2900	3280	3600	4050	4400	5200	5760		5'1"
16'	2720	3100	3515	3900	4350	4800	5640	6450	6640	5'2"
18'	2840	3275	3720	4150	4620	5100	6040	7050	7500	5'4"
20'	3000	3400	3995	4350	4860	5350	6400	7450	8410	5'7"

Pipe Size 21" I.D.

TRENCH COVER	TRENCH WIDTH										TRANSITION WIDTH
	2'9"	3'0"	3'3"	3'6"	3'9"	4'0"	4'6"	5'0"	5'6"	6'0"	
2'	570										2'9"
2'6"	745	730									2'11"
3'	870	915									3'2"
4'	1110	1250	1330	1380							3'6"
5'	1320	1450	1610	1750	1860						3'10"
6'	1520	1700	1865	2050	2210	2325					4'1"
7'	1690	1900	2090	2300	2515	2700	2795				4'4"
8'	1850	2100	2320	2525	2765	3000	3260				4'6"
9'	2000	2250	2510	2750	3040	3300	3725				4'7"
10'	2120	2400	2725	2950	3240	3550	4140	4210			4'9"
12'	2360	2675	3020	3300	3660	4000	4660	5160			5'0"
14'	2570	2900	3280	3600	4050	4400	5200	6000	6100		5'3"
16'	2720	3100	3515	3900	4350	4800	5640	6450	7020		5'5"
18'	2840	3275	3720	4150	4620	5100	6040	7050	7950		5'6"
20'	3000	3400	3995	4350	4860	5350	6400	7450	8460	8920	5'8"

Pipe Size 24" I.D.

TRENCH COVER	TRENCH WIDTH										TRANSITION WIDTH
	3'0"	3'3"	3'6"	3'9"	4'0"	4'6"	5'0"	5'6"	6'0"	6'6"	
2'	630										3'1"
2'6"	805	810									3'3"
3'	955	1010	1010								3'5"
4'	1250	1330	1400	1490							3'9"
5'	1450	1610	1750	1940	2030						4'1"
6'	1700	1865	2050	2210	2400	2550					4'5"
7'	1900	2090	2300	2515	2700	3080					4'8"
8'	2100	2320	2525	2765	3000	3480	3620				4'10"
9'	2250	2510	2750	3040	3300	3790	4130				5'0"
10'	2400	2725	2950	3240	3550	4140	4660	4660			5'2"
12'	2675	3020	3300	3660	4000	4660	5400	5740			5'5"
14'	2900	3280	3600	4050	4400	5200	6000	6750	6800		5'8"
16'	3100	3515	3900	4350	4800	5640	6450	7410	7850		5'11"
18'	3275	3720	4150	4620	5100	6040	7050	8000	8910		6'1"
20'	3400	3995	4350	4860	5350	6400	7450	8460	9600	10000	6'2"

Pipe Size 27" I.D.

TRENCH COVER	TRENCH WIDTH										TRANSITION WIDTH
	3'3"	3'6"	3'9"	4'0"	4'6"	5'0"	5'6"	6'0"	6'6"	7'0"	
2'	710										3'5"
2'6"	895	905									3'6"
3'	1040	1095									3'8"
4'	1330	1400	1540	1600							4'1"
5'	1610	1750	1940	2050	2200						4'6"
6'	1865	2050	2210	2400	2785						4'8"
7'	2090	2300	2515	2700	3110	3385					5'1"
8'	2320	2525	2765	3000	3480	3900	3980				5'3"
9'	2510	2750	3040	3300	3790	4300	4590				5'6"
10'	2725	2950	3240	3550	4140	4700	5190				5'7"
12'	3020	3300	3660	4000	4660	5400	6060	6390			6'0"
14'	3280	3600	4050	4400	5200	6000	6750	7550	7560		6'3"
16'	3515	3900	4350	4800	5640	6450	7410	8300	8800		6'6"
18'	3720	4150	4620	5100	6040	7050	8000	9000	9960	10000	6'8"
20'	3995	4350	4860	5350	6400	7450	8460	9600	10890	11180	6'10"

Pipe Size 30" I.D.

TRENCH COVER	TRENCH WIDTH									TRANSITION WIDTH
	3'6"	4'0"	4'6"	5'0"	5'6"	6'0"	6'6"	7'0"	7'6"	
2'	755									3'7"
2'6"	965									3'10"
3'	1150	1185								3'11"
4'	1400	1675	1680							4'5"
5'	1750	2050	2335	2340						4'8"
6'	2050	2400	2800	3005						5'0"
7'	2300	2700	3110	3500	3665					5'5"
8'	2525	3000	3480	3900	4320					5'7"
9'	2750	3300	3790	4300	4840	4980				5'10"
10'	2950	3550	4140	4700	5260	5660				6'1"
12'	3300	4000	4660	5400	6060	6800	6990			6'5"
14'	3600	4400	5200	6000	6750	7550	8320	8320		6'9"
16'	3900	4800	5640	6450	7410	8300	9210	9610		7'0"
18'	4150	5100	6040	7050	8000	9000	9960	10980	10980	7'3"
20'	4350	5350	6400	7450	8460	9600	10890	11890	12300	7'5"

Pipe Size 33" I.D.

TRENCH COVER	TRENCH WIDTH										TRANSITION WIDTH
	3'9"	4'0"	4'6"	5'0"	5'6"	6'0"	6'6"	7'0"	7'6"	8'0"	
2'	810										3'10"
2'6"	1050	1060									4'1"
3'	1220	1290									4'3"
4'	1540	1675	1815								4'6"
5'	1940	2050	2335	2445							5'1"
6'	2210	2400	2800	3050	3205						5'5"
7'	2515	3000	3110	3500	3920	3925					5'8"
8'	2705	3300	3480	3900	4460	4640					6'1"
9'	3040	3550	3790	4300	4840	5400	5610				6'3"
10'	3240	4000	4140	4700	5260	5900	6070				6'5"
12'	3660	4400	4660	5400	6060	6800	7450	7550			6'10"
14'	4050	4800	5200	6000	6750	7550	8350	9030			7'2"
16'	4350	5100	5640	6450	7410	8300	9210	10110	10470		7'5"
18'	4620	5350	6040	7050	8000	9000	9960	11060	12120		7'9"
20'	4860	5575	6400	7450	8460	9600	10890	11890	13020	13390	7'11"

Pipe Size 36" I.D.

TRENCH COVER	TRENCH WIDTH										TRANSITION WIDTH
	4'0"	4'6"	5'0"	5'6"	6'0"	6'6"	7'0"	7'6"	8'0"	8'6"	
2'	920	925									4'3"
2'6"	1130	1145									4'4"
3'	1325	1550									4'7"
4'	1675	1950	1950								4'11"
5'	2050	2335	2555	2555							5'3"
6'	2400	2800	3050	3340	3340						5'8"
7'	2700	3110	3500	3920	4160						6'0"
8'	3000	3480	3900	4460	4900	4950					6'2"
9'	3300	3790	4300	4840	5400	5760	5760				6'8"
10'	3550	4140	4700	5260	5900	6430	6540				6'10"
12'	4000	4660	5400	6060	6800	7450	8150	8150			7'4"
14'	4400	5200	6000	6750	7550	8350	9170	9750	9750		7'8"
16'	4800	5640	6450	7410	8300	9210	10110	11000	11330		7'11"
18'	5100	6040	7050	8000	9000	9960	11060	12150	12900	12900	8'2"
20'	5350	6400	7450	8460	9600	10890	11890	13020	14140	14510	8'6"

APPENDIX D

LIVE LOADS—COMPUTATIONS

$$W_{sc} = C_s \frac{PF}{L}$$

Where:

W_{sc} = Load on the conduit in pounds per lineal foot

P = superimposed concentrated load in pounds

F = Impact factor used as a contingency against the effect of a dynamic load (See Table for

impact factor)

L = Length of the conduit (use 3' for conduits greater than 3' in length)

C_s = Load coefficient which is a function of the width of the conduit and the height of the backfill (see the following Table for values of C_s for pipe 18" to 36" in diameter and covers of 2' to 20')

C_s VALUES OF LOAD COEFFICIENTS C_s FOR CONCENTRATED SUPERIMPOSED LOADS CENTERED VERTICALLY OVER CONDUIT											
PIPE SIZE ID	DEPTH OF COVER										
	2'	2'6"	3'	4'	5'	6'	8'	10'	12'	16'	20'
18"	0.391	0.289	0.221	0.136	0.092	0.066	0.038	0.025	0.017	0.010	0.006
20"	0.422	0.316	0.241	0.150	0.102	0.073	0.042	0.027	0.019	0.011	0.007
21"	0.436	0.327	0.251	0.157	0.107	0.077	0.044	0.029	0.020	0.012	0.0075
24"	0.478	0.362	0.280	0.177	0.120	0.087	0.050	0.033	0.022	0.013	0.0080
27"	0.510	0.392	0.306	0.195	0.133	0.096	0.056	0.037	0.025	0.014	0.0085
30"	0.543	0.423	0.332	0.213	0.147	0.106	0.062	0.041	0.029	0.016	0.010
33"	0.563	0.446	0.353	0.230	0.159	0.115	0.067	0.045	0.032	0.018	0.011
36"	0.590	0.470	0.375	0.248	0.171	0.124	0.073	0.049	0.035	0.020	0.012

F IMPACT FACTOR TABLE*	
DEPTH OF COVER	IMPACT FACTOR (F)
1'—2'	1.2
2'—3'	1.1
3' or more	1.0
*A.A.S.H.O. STANDARD SPEC. FOR HIGHWAY BRIDGES SEC. 1-2-12(A) AND (C), 1961 EDITION.	

W_{SC}

**SUPERIMPOSED (WHEEL) LOAD ON J-M
TRANSMISSION PIPE — SINGLE WHEEL = 10,000 LB**

COVER OVER TOP OF PIPE	PIPE DIAMETER							
	18"	20"	21"	24"	27"	30"	33"	36"
2'	1302	1407	1450	1591	1700	1810	1870	1968
2'6"	964	1051	1080	1212	1307	1410	1480	1569
3'	736	804	834	934	1020	1108	1174	1250
4'	453	500	523	590	650	710	765	826
5'	306	340	356	400	444	490	528	570
6'	220	243	256	290	320	354	382	414
8'	127	140	146	167	187	206	223	244
10'	83	90	96	110	123	137	150	163
12'	57	63	66	73	83	97	106	117
16'	33	37	40	43	47	53	60	67
20'	20	23	25	27	28	33	37	40

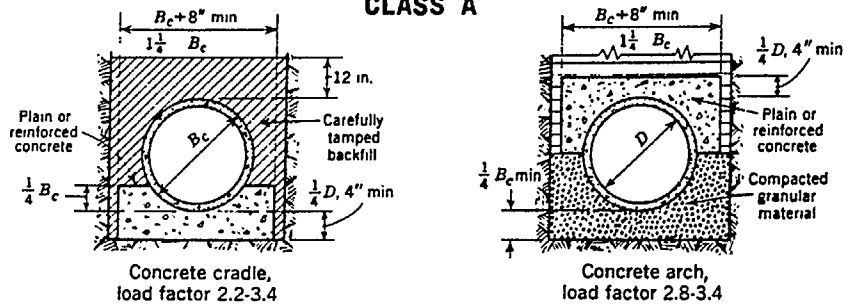
VALUES SHOWN ARE IN LBS/LIN FT OF PIPE
NOTE: TABLE IS BASED ON IMPACT FACTOR OF ONE. IF
IMPACT IS TO BE USED SIMPLY MULTIPLY VALUE FROM TABLE
TIMES DESIRED IMPACT FACTOR.



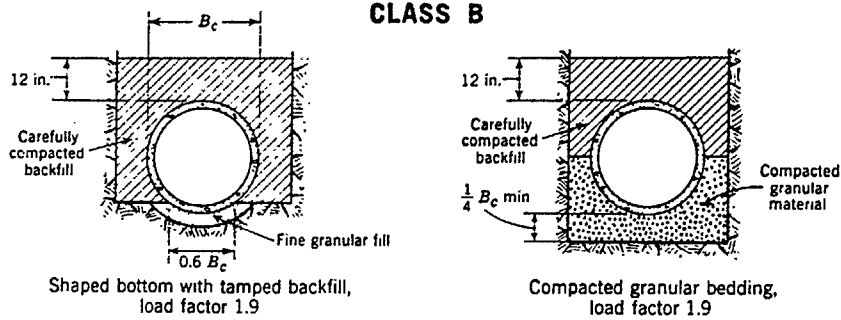
APPENDIX E

CORRELATION OF BEDDING CONDITIONS AND LOAD FACTORS*

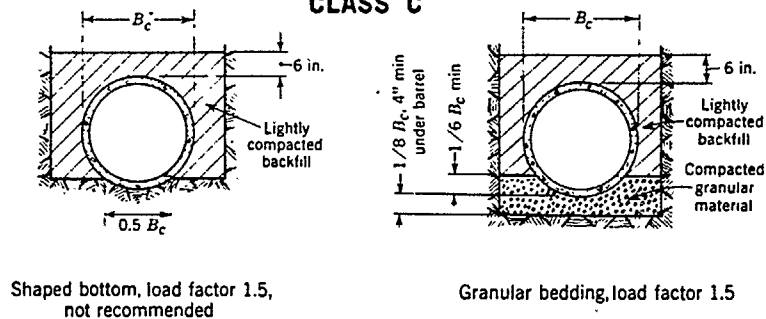
CLASS A



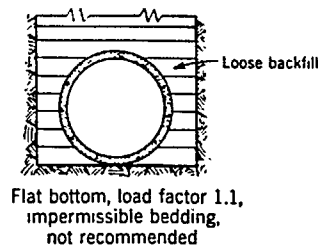
CLASS B



CLASS C



CLASS D



*WPCF Manual of Practice No. 9 "Design and Construction of Sanitary and Storm Sewers".



APPENDIX F

Water Hammer and Surge—Analysis and Control

The slowing down or stopping of any moving mass requires a force or forces to counterbalance the kinetic energy that keeps it in motion. The faster the mass is decelerated and brought to a halt, the greater the force that is required.

It is somewhat an oversimplification, but water hammer or surge can be defined in these terms. The shutting of a valve or the stopping of a pump causes a moving column of water in a pipeline to slow down and stop. The forces that bring about this deceleration are exerted radially on the moving water column by the pipeline walls. Conversely the water exerts added pressure on the pipe and the hoop stress in the pipe walls thus increases over the normal operating pressure values. The faster the column of water is brought to a halt, the higher these stresses rise.

The pipe wall stresses then are developed by, and increase in direct proportion to, the internal pressure which builds up as the column of water decelerates. The slower the deceleration, the less the pressure build up and the less the pipe wall stress increases. It is, therefore, of importance to the pipe designer to know how to control the rate of velocity fluctuation and, consequently, the magnitude of pressure variations during transitional periods. By such control he can keep pipe wall stresses during surge to a predetermined value leading to an economical installation.

Water, being a liquid, will act in a fairly complex manner when undergoing acceleration or deceleration. Pressure waves are set up which move along the pipeline at a rate of 2500 to 4500 feet per second depending on pipe wall material. These will continue until they encounter a boundary condition such as a reservoir, a closed valve or change in pipe diameter, and will then reflect back in the opposite direction. The wave motion will oscillate back and forth in the pipe until it is dampened out by friction effects on the pipe walls.

The two major causes of water hammer or surge are:

1. The closing or opening fully or partially of a valve in a pipeline system. The valve may be in the line for one of a number of purposes. It could be a gate valve, float valve, pressure reducing valve, etc.
2. The starting up or shutting down a pump (switch or power failure).

It can be seen that both of these occurrences cause changes in the velocity and consequently the quantity of water flowing in the pipeline.

Ignoring the effects of surge in the pipeline can lead to difficulties after the line is in operation. Surges can result in damaged equipment and seriously reduced capacity.

WATER HAMMER ANALYSIS

The elastic wave theory for surge analysis has been empirically established as correct by many experiments starting as early as 1890. Its application to pipeline problems will yield results which are accurate and may be relied upon for adequate analysis.

Water hammer pressures are a function of the maximum rate of change of flow. When a valve is closed or a pump stops, a pressure wave is propagated along a pipeline. The velocity of that wave is the same as the velocity of sound in water modified by physical characteristics of the pipeline and is given by the following equation:

$$a = \frac{4660}{\sqrt{1 + \frac{kd}{Ee}}}$$

Where: a = Pressure wave velocity (ft./sec)

k = Modulus of compression of water
(300,000 psi)

d = Internal diameter of pipe in inches

E = Modulus of elasticity of A-C pipe
(3,400,000 psi)

e = Wall thickness in inches

4660 = Velocity of sound in water (ft./sec.)

If the pressure wave is reflected back from a boundary condition such as a reservoir and reaches its initial position after the flow in the line is completely stopped, then maximum water hammer pressure for those conditions will result. Stopping of the flow may be effected by closing a valve or a pump stoppage. The magnitude of that maximum pressure is given by:

$$h = \frac{aV}{g}$$

Where: h = Surge pressure in feet of water

V = Velocity of water in the pipeline during normal conditions—ft./sec.

a = Velocity of the pressure wave—ft./sec.

g = Acceleration due to gravity = 32.2 ft./sec.²

The longest elapsed time before final flow stoppage that will still permit this maximum pressure to occur is called the critical time and is simply the total length the pressure wave travels in one cycle divided by the velocity of the wave. It is given by the following equation:

$$U = \frac{2L}{a}$$

Where: U = The critical time, seconds

L = Distance within the pipeline that the pressure moves before it is reflected back by a boundary condition—feet

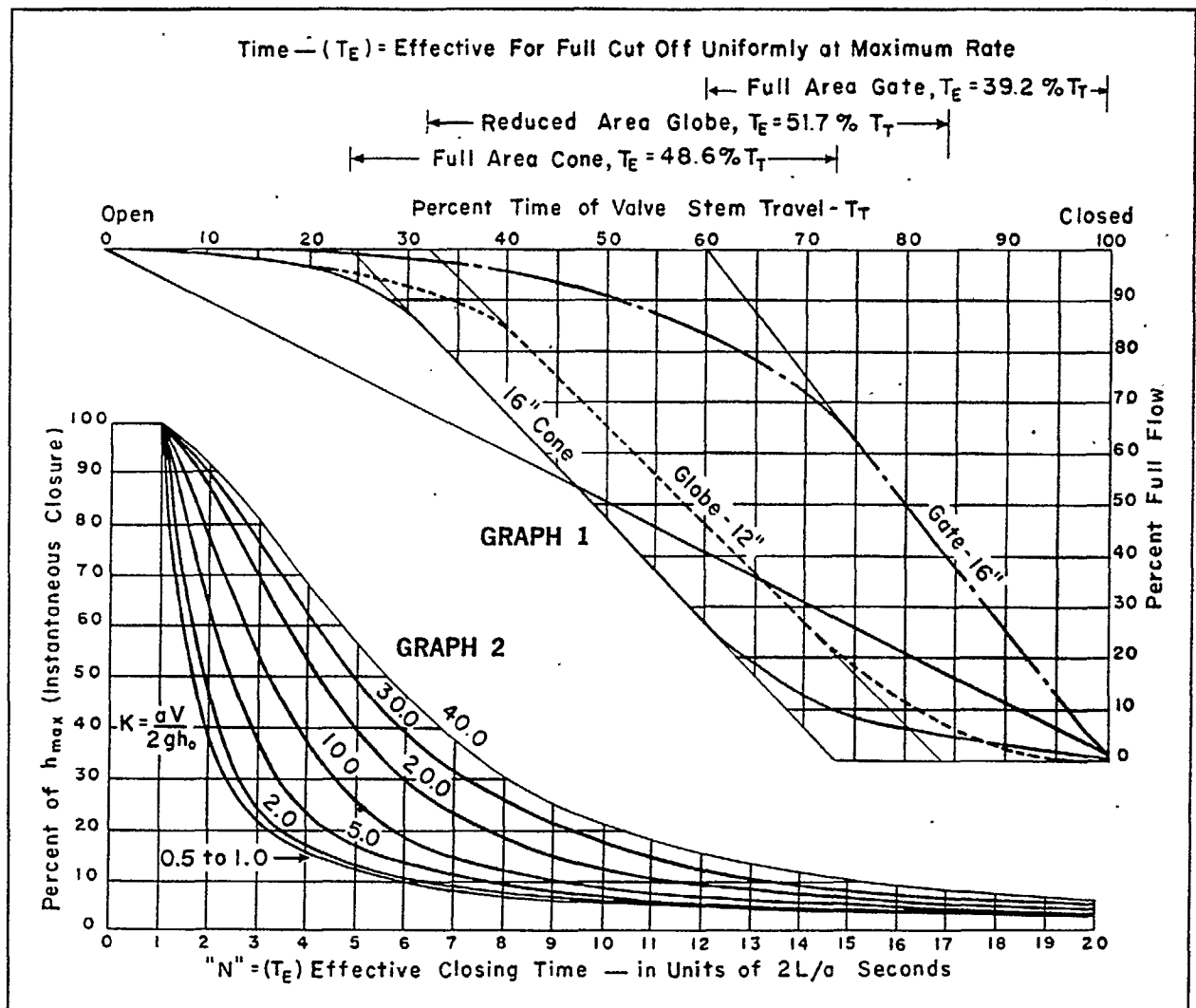
a = Velocity of the pressure wave = feet/sec.

VALVE CLOSURE

A valve in a water line may be of a number of different varieties including gate, cone, and globe valves.

In closing a valve, the area of the cross section of the pipeline progressively cut off is not generally proportional to the reduction in flow. Graph 1 presents a plot of stem travel vs. flow in the line for three types of valves. Note that the first 30-40% of stem travel has little effect on the flow in the pipeline.

As stated previously water hammer pressure is a function of the maximum rate of change of flow. Therefore, if tangents to the curves on Graph 1 are drawn at the fastest rate of change (or steepest slope), the effective time of closure (T_E) is obtained. (See curves on Graph 1 with tangents plotted and valves of T_E determined.) This "effective time" is the time that is used in water hammer calculations. It is, in most cases, about one-half of the actual valve closing time. This indicates that if the critical time of a certain valve is calculated from the formula $\frac{2L}{a}$ and found to be X seconds, then the actual time of valve closure for this condition will be approximately $2X$ seconds.



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In the design of a water system one of the major considerations in the selection of a pipe is the "design internal pressure" that the pipe will be required to carry in service. The "design internal pressure" is the operating pressure plus the water hammer pressure. In order to keep the water hammer or surge pressures at a controlled level, calculations must be made to determine the times of valve closure that will be required to stay within the design pressure level.

Graph 2 presents a convenient method for determining effective valve closure times for a given percentage of the maximum pressure (surge pressure when valve is closed in less than the critical time). First, determine the pipeline constant K given by:

$$K = \frac{aV}{2gh_0}$$

Where: K = Pipeline constant

a = Velocity of the pressure wave in the line (ft./sec.)

V = Velocity of water in the flow line under normal conditions (ft./sec.)

g = Acceleration due to gravity (32.2 ft/sec²)

h₀ = Operating pressure in the line under normal conditions (ft. of water)

Second, determine the maximum head that might be developed from the surge by employing the formula $h_{max} = \frac{aV}{g}$. Third, determine the percentage of h_{max} to be controlled. Enter Graph 2 with the K value plus the percentage h_{max} and find the corresponding effective closing time shown on the horizontal axis. This is given in units of $\frac{2L}{a}$ which represents the critical time for the pipeline. Note that the time determined is the "effective" closing time and the actual time of valve stem travel is about twice as long. The reason being is that the first half of the closing of the valve has little effect on the stoppage of the flow. It is the closing of the final half of the valve stem travel which closes off the flow. The second half is the "effective" closing time. Therefore, two times the effective closing time is the actual time of the valve stem travel.

PUMPED SYSTEMS

In relation to water hammer and surge the most important elements in a system are pumps and valves. In a gravity system valves only have to be considered. Both must be considered in a pumped system.

The surge analysis of a pumped system is more complex than in a purely gravity system because:

- a. In a pumped system the problem begins with the slowing down of the rising water column when the pump is shut off because of power failure or otherwise. Consideration must be

given to the time required for the pump to stop and the flow to come to a halt. This involves the inertia of the motor and any flywheel in the assembly. In a gravity system the hydraulic problem consists only of stopping the descending water column.

- b. The pipeline profile is usually irregular with successive high and low points and variable slopes. These conditions may give rise to water column separation causing severe surges and operational troubles. Surges from water column separation do not follow a standard pattern and have been measured at many times the calculated values.

The design of a pumped system may involve the consideration of alternative layouts to keep surges and the consequent operational difficulties to a minimum. This work would be directed toward (a) reducing the magnitude of surges and (b) reduce the risk of water column separation that may be caused by the shut down of a pump.

Water column separation can be serious due to the large magnitude of the surges developed when the water column rejoins. It can occur:

- a. At pump locations at start of a steep main.
- b. When the pressure at a high point falls below atmospheric and air enters the line through air valves that may be located at a high point.
- c. When the pressure falls to below vapor pressure of water.

Water column separation can cause difficulties not only because of the before-mentioned surges set up by rejoining of the water column, but because of the difficulties in getting air out of the line on subsequent start up even with air valves. Entrapped air can cause flow fluctuations and seriously reduce the capacity of the system.

METHODS OF CONTROL

The two types of surge to be controlled are negative surge and positive surge. The type is determined, of course, by whether the surge pressures developed are below or above the normal static level.

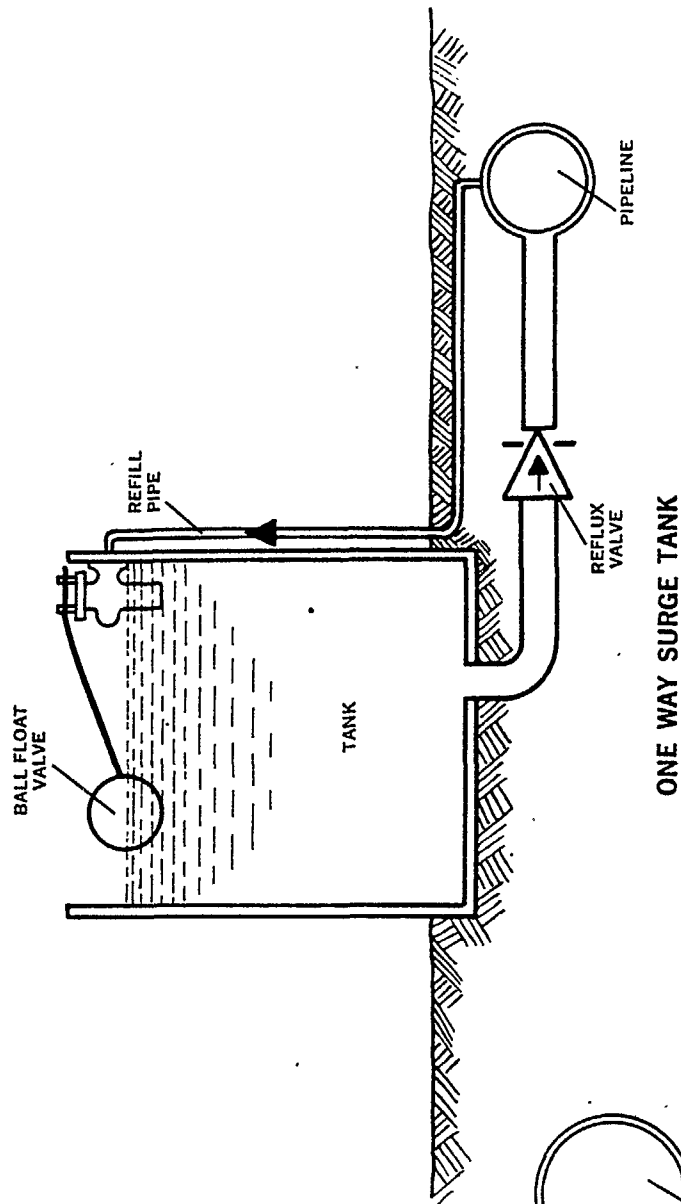
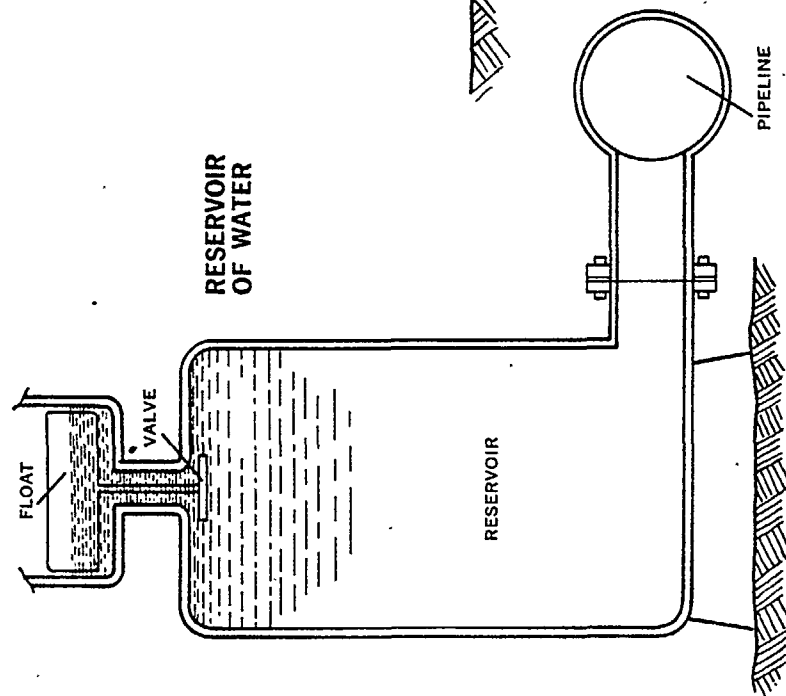
Negative surges in themselves are usually not dangerous, except when they cause water column separation. If this occurs extremely high positive surges result when the cavity closes frequently causing serious problems. The control of both negative and positive surges should be given consideration.

TYPES OF SURGE CONTROL DEVICES

Limiting negative and positive surges.

1. Flywheel on pump motor—In the event of a power outage the inertia of the flywheel will

SURGE CONTROL DEVICES



keep the pump running for a period of time gradually slowing to a stop. This means that the water column in the pipeline will also be brought to a stop gradually reducing the risk of water column separation.

2. **Standpipe**—This is generally a tank with the surface of the water at atmospheric pressure. It is, therefore, only practical at low heads. At a pump stoppage and consequent reduced pressure, the reserve of water in the tank flows into the pipe and reduces the risk of water column separation. For positive surge control the tank provides an outlet for the build-up pressure in the system.
3. **Air Vessel or Surge Tank**—This is an enclosed vessel containing air and water. It functions similar to a standpipe. The major difference is that the air in the vessel is under pressure and much higher heads can be employed in the pipe system. The principle is the same with water re-entering the line during negative surge and leaving during positive surge.
4. **One way surge tank**—This is an adaption of the surge tank that contains a check valve which permits water to enter the line during negative surge but will not permit water to leave during positive surge. It is, therefore, only for control of negative surges and is very effective.
5. **Reservoir of Water**—This is similar to the one-way surge tank, but provides some control of positive surge by permitting the slow entrance of water into the reservoir during a positive surge.
6. **Suction Pipe**—This is a bypass around the pump from the suction side. It contains a check valve to prevent backflow into the reservoir. It effectively reduces negative pressure adjacent to the pump.
7. **Surge relief valve**—This is used for controlling positive surges only. The valve opens at a certain pressure and discharges water to relieve the surge. They must be carefully designed and controlled to be effective.
8. **Non-return valve**—A check strategically placed in a line can bring a small measure of relief to positive pressure. However, unless properly placed, it can lead to higher surge rather than lower.
9. **Reversal of pump**—At pump stoppage the column of water reverses itself. If the pump will

not run backwards to permit water to flow back through it, positive surges will be developed with a sudden stopping of the backflowing column of water. The pump should be designed to run reversed without damage to itself.

10. **Controlled valves**—This is one of the most effective means for controlling positive surges. As explained previously the rate of closing of a valve can be calculated to allow an acceptable level of surge.

From an economic standpoint, it is usually very worthwhile to properly evaluate the surge potential in a system under design. The cost of control devices may be balanced against the added strength of pipe, valves and other equipment if surges are not controlled and the most advantageous conclusion reached.

Manufacturers of surge control equipment or consultants in this field should be sought for advice in the complex situations.

SURGE CALCULATION EXAMPLE

The following example illustrates the calculation that may be followed in the determination of valve closing time for the control of surge within prescribed limits.

A 24" gravity transmission line is to operate at a pressure of 100 psi. Velocity in the line is to be 5 f.p.s. A valve is to be included in the line at a distance of 5,000 feet from the reservoir. If positive surge pressure is to be controlled within 50 psi, determine the minimum time for valve closure. Assume that the effective closing time is one-half of the actual valve stem travel time. (E for A-C = 3.4×10^6 , wall thickness is 1.5", k for water = 3×10^5 .)

1. Determine surge wave velocity

$$a = \frac{4660}{\sqrt{1 + \frac{kd}{Ee}}} = \frac{4660}{\sqrt{1 + \frac{3 \times 10^5 \times 24}{3.4 \times 10^6 \times 1.5}}} = 3000 \text{ ft./sec.}$$

2. Determine maximum surge pressure if the valve closes within the critical time

$$h = \frac{aV}{g} = \frac{3000 \times 5}{32.2} = 465 \text{ ft. of water (200 psi)}$$

3. Determine the critical time

$$u = \frac{2L}{a} = \frac{2 \times 5000}{3000} = 3.33 \text{ sec.}$$

4. Determine Constant "K" for use in Graph 2

$$K = \frac{aV}{2gh_0} = \frac{3000 \times 5}{2 \times 32.2 \times 231} = 1.0$$

5. Determine percent of maximum surge pressure that should not be exceeded in the system.

$$\frac{50}{200} \times 100 = 25\%$$

6. Enter Graph 2 with percent of h_{max} (25%). Go horizontally to the curves where $K = 1.0$. Read the effective closing time along the horizontal axis. This value is 2.6 and is given in units of

$2L/a$ seconds. The effective closing time in seconds would be $2L/a \times 2.6 = 3.33 \times 2.6 = 8.7$ sec. The actual valve stem travel time would be twice this amount or 17.4 sec. This calculated time (17.4 sec.), therefore, represents the fastest allowable time the valve can be closed in order to keep the surge pressure below the desired control level of 50 psi.



APPENDIX G

Air in Pipelines

Air in pipelines can cause serious operational difficulties including reduction in capacity because of reduced cross-sectional area and fluctuation in flow caused by expanding and contracting of the air in the line. Serious surges can be set up by these fluctuations in flow which cause sudden movements of the air from one location to another followed by slugs of water.

Air can enter a pipeline in many ways including:

- a. At the intake
- b. Release of air from water by temperature and pressure variation
- c. On draining the line
- d. Draining of parts of the line occurring during normal shut-down
- e. Negative surges causing air to enter at air valves

Air should be prevented from entering the line in the first place. This is very important to reduce operational difficulties.

Suggested solutions for control are as follows:

- a. Intake—Correct design procedures, provide low water level pump cut-off
- b. Release of air—Air is entrained in the water at intake and its release cannot be prevented. However, the quantities are not large and provisions for exhausting can be made by means of air valves. There are various types of air valves with different functions, and the selection of the proper type is essential.
- c. Draining the line—On draining, air, of course, cannot be prevented from entering the line. Large orifice air valves should be provided for exhausting the air during refilling. Refilling does not often occur and, therefore, long filling times may be satisfactory.
- d. Drainage during shut down—This can be a serious problem. Open standpipes can be provided for air entry and exhaust. Sweeping air out using high velocities is also a method.

- e. Negative surges—The best way to prevent air from entering under these conditions is to design out the possibility of water column separation. Large volumes of air may be involved here and can cause serious problems. Any one of the negative surge control devices described in Appendix F will normally be adequate.

RECOMMENDATIONS TO COMBAT AIR ENTRAPMENT

Colorado State University has conducted studies to determine the effect of Air Entrapment in Pipe Lines. The result of the studies proved that suddenly released entrapped air, under apparently static conditions, creates a situation similar to that of classic water hammer. Pressures are generated which may be in the order of 15 times the pipe line test pressure. Any pipe line material is seriously affected by this rapid magnitude of load increase. Hydrostatic failure due to "defective pipe" may in all probability be traced to suddenly released entrapped air. The initial filling and testing of a pipe line is often the most critical period of its service life.

Recommendations to combat air entrapment were made as follows:

1. Pipe line should be laid to grade wherever possible.
2. Automatic "continual acting" air release valves should be used at all high points.
3. Air should be bled from pipe line *slowly*.
4. Limit filling velocity in the pipe line to one foot per second or less.
5. Use $d/D = 1/10$ to $1/100$.
 d = diameter of air release valve.
 D = pipe diameter.

The results of this study, together with the recommendations, have been found most useful to contractors in performing pipe line tests. Such recommendations have been found useful also to engineers from the standpoint of designing air out of pipe lines.



APPENDIX H

Combined Loading Curves for Pipe Sizes 18'' to 36''

DESIGN INTERNAL PRESSURE AND DESIGN EXTERNAL LOAD INTERCEPTS FOR USE WITH SELECTION CURVES							
PIPE SIZE	T-30	T-35	T-40	T-45	T-50	T-60	T-70
	P=300 psi	P=350 psi	P=400 psi	P=450 psi	P=500 psi	P=600 psi	P=700 psi
	W lbs/lin ft	W lbs/lin ft	W lbs/lin ft	W lbs/lin ft	W lbs/lin ft	W lbs/lin ft	W lbs/lin ft
18"	2,500	3,000	4,000	5,000	6,500	8,500	11,000
20"	2,500	3,500	4,500	5,500	7,100	9,500	12,000
21"	2,500	3,500	4,500	5,800	7,300	9,700	12,500
24"	2,800	3,800	5,000	6,200	8,100	11,000	15,000
27"	3,500	4,200	5,500	7,000	8,800	12,500	16,500
30"	3,500	4,500	6,000	7,500	9,700	13,500	18,000
33"	3,500	5,000	6,500	8,000	10,500	14,500	19,500
36"	4,000	5,000	7,000	9,000	11,200	16,000	21,000

$$w = W \sqrt{\frac{P - p}{P}} \quad \text{or} \quad p = P(1 - \frac{w^2}{W^2})$$

Where:

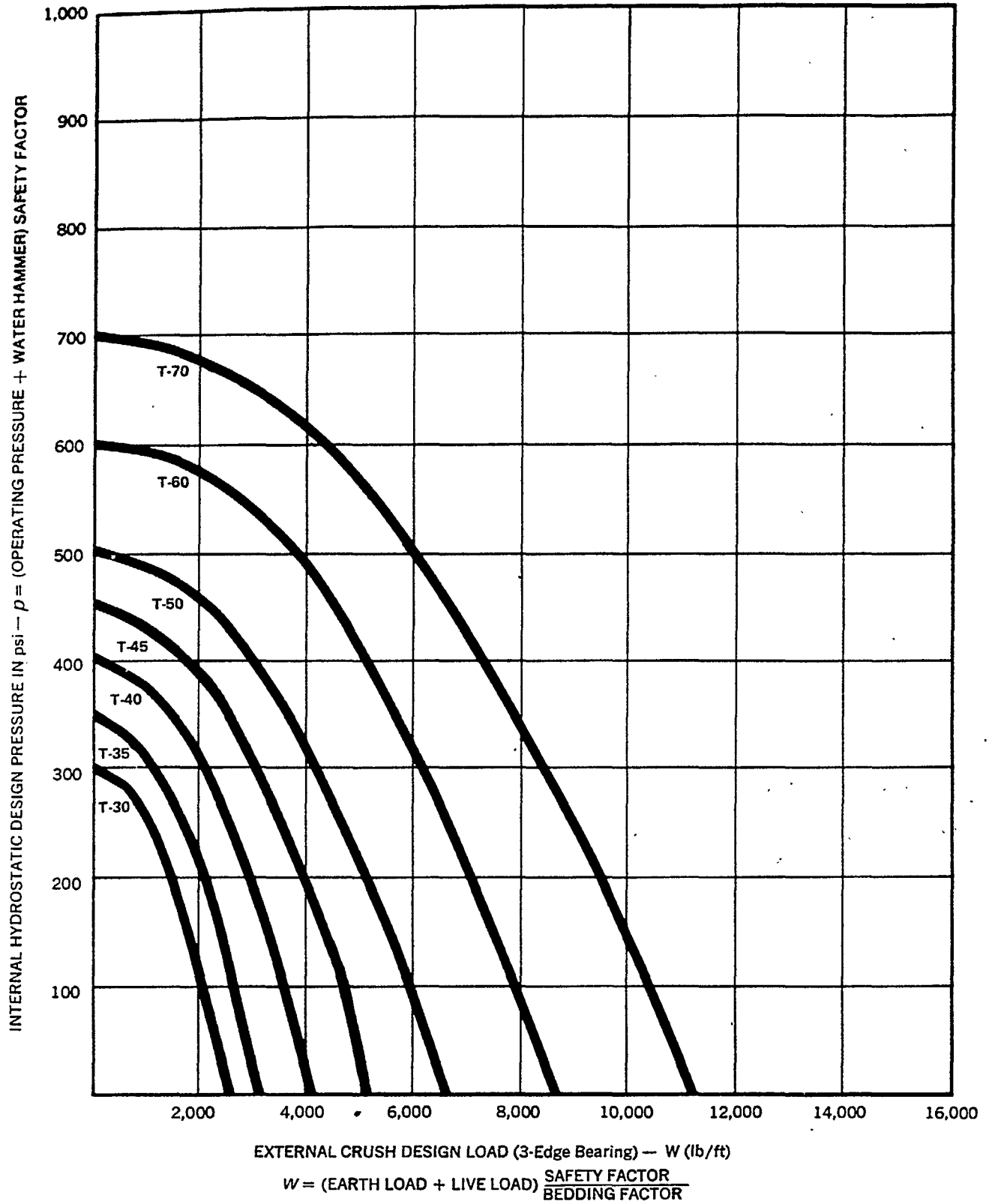
P = the internal hydrostatic design pressure for the pipe when no external load exists—psi.

W = the external crushing design load for the pipe (3-edge bearing test) when no internal pressure exists—lbs/ft of pipe.

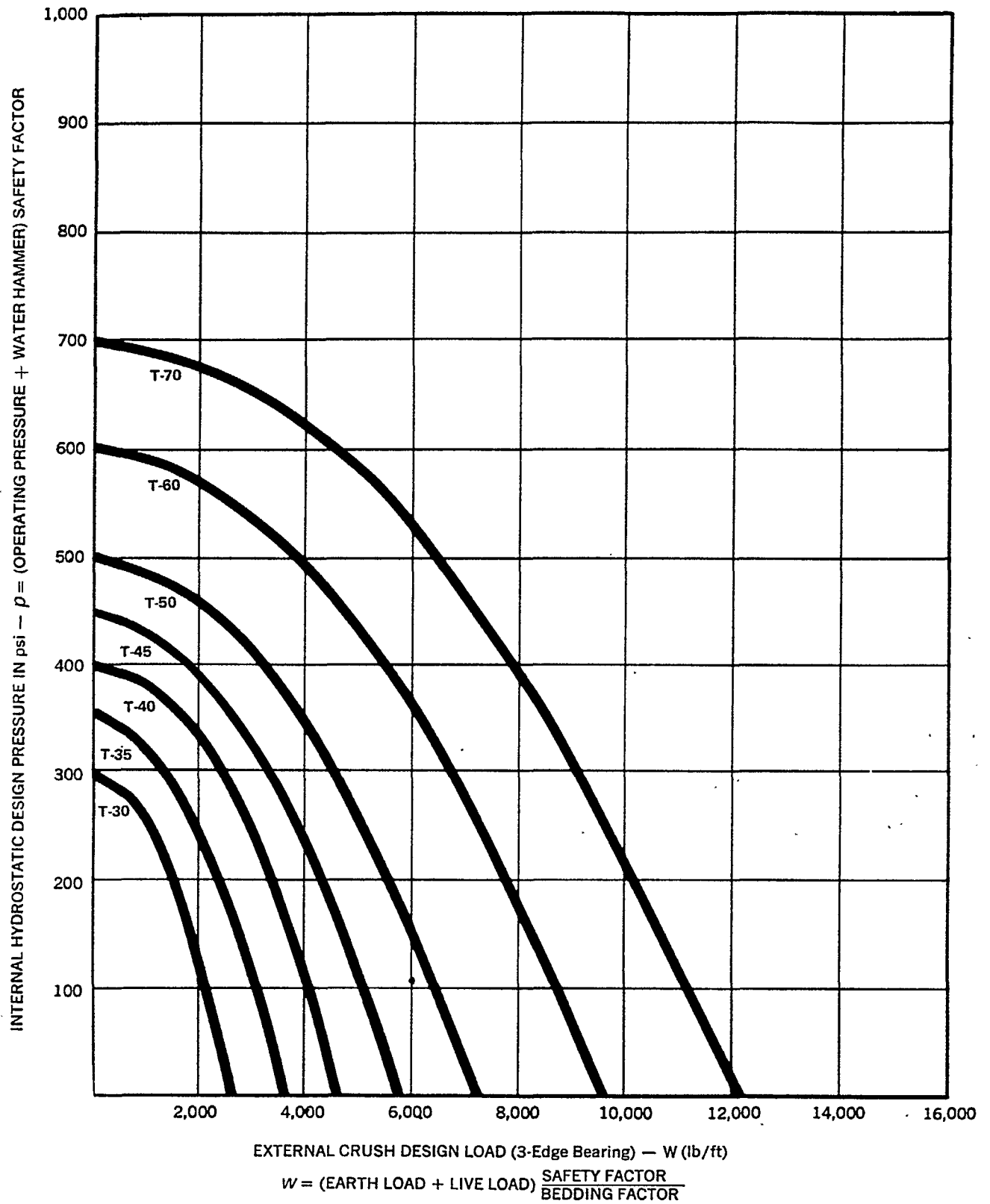
p = the internal hydrostatic pressure for that pipe when an external crushing load (w) is acting simultaneously—psi.

w = external crushing load for the pipe when an internal pressure (p) is also acting on the pipe—lbs/ft of pipe.

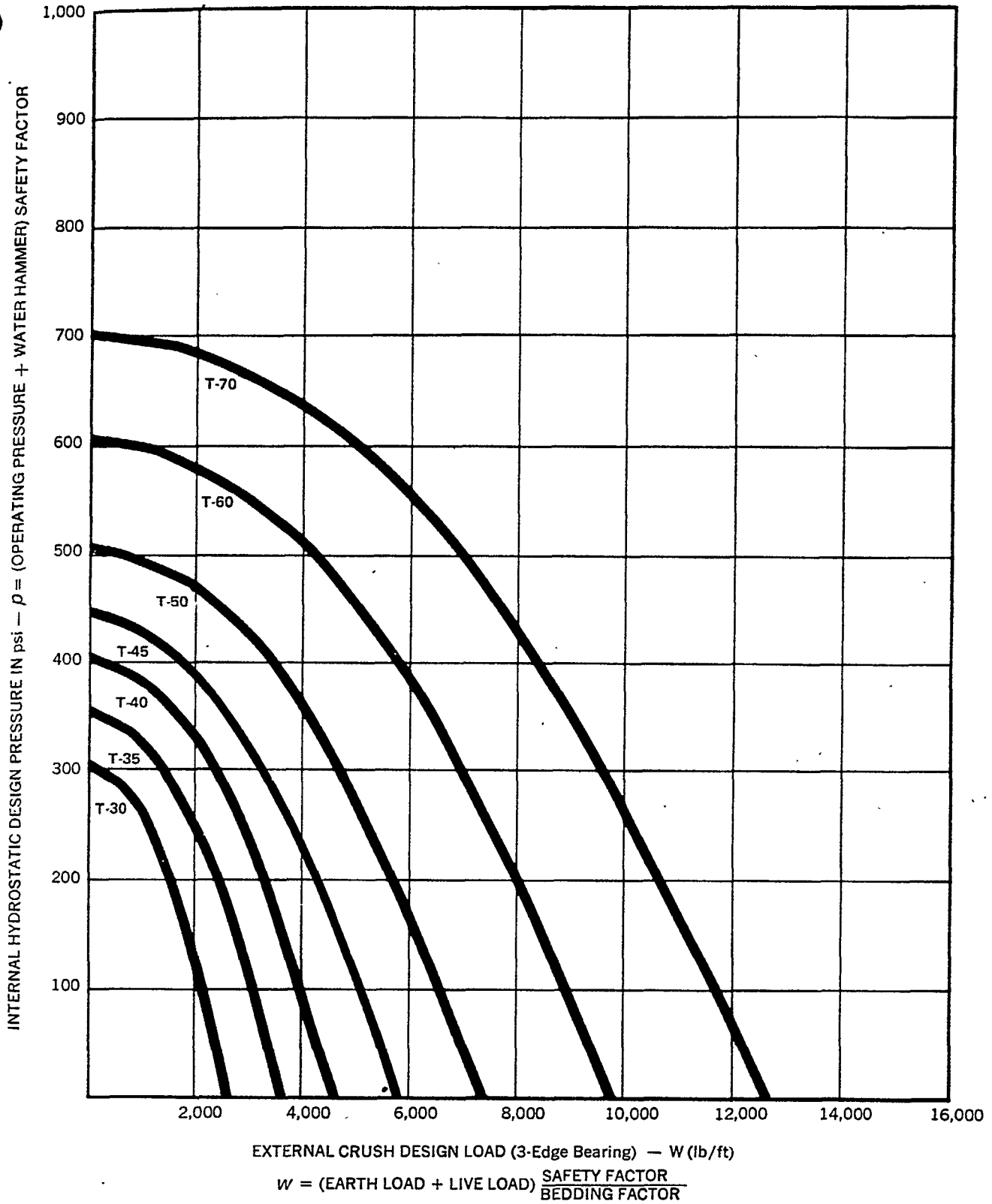
18" TRANSMISSION PIPE



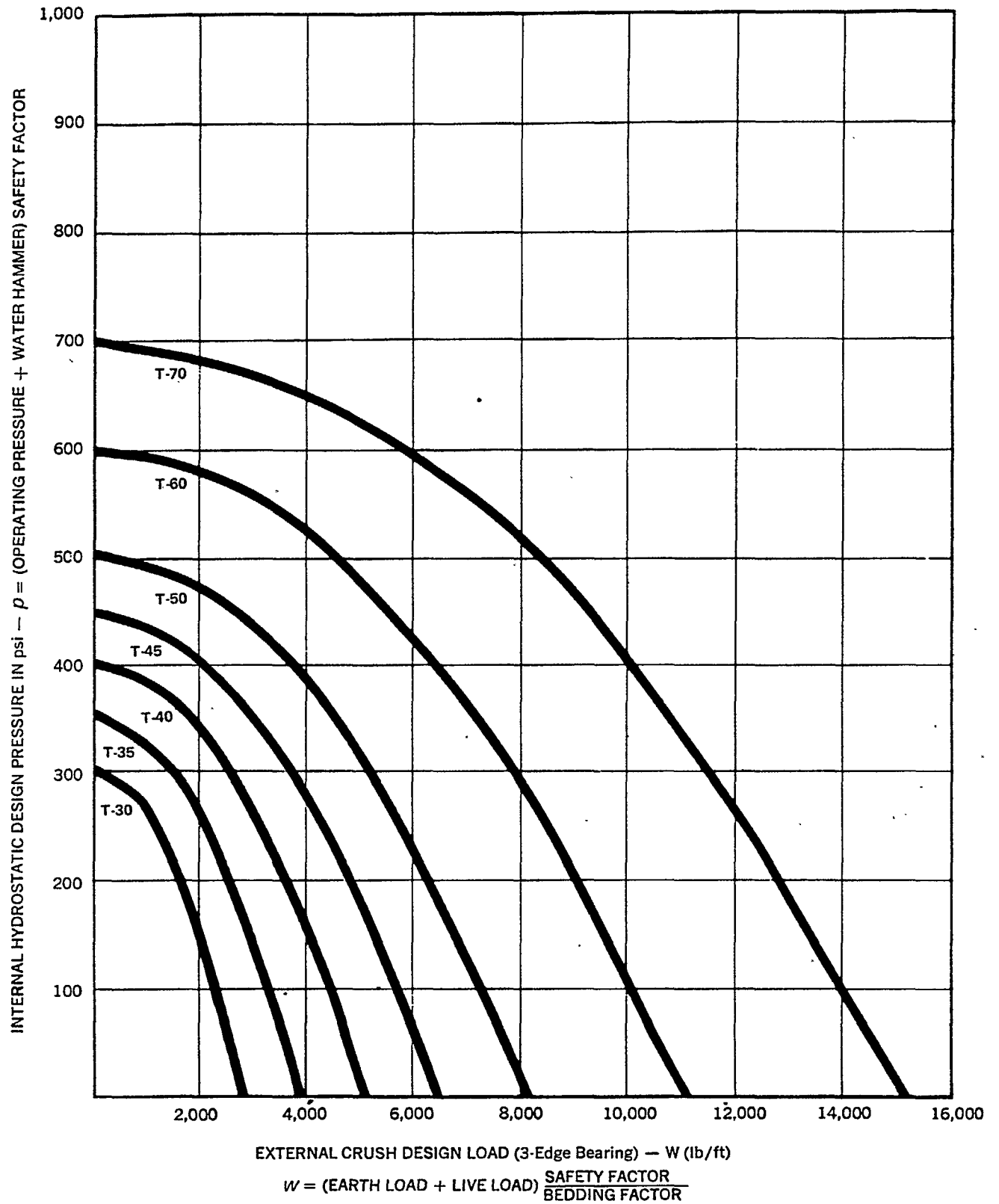
20" TRANSMISSION PIPE



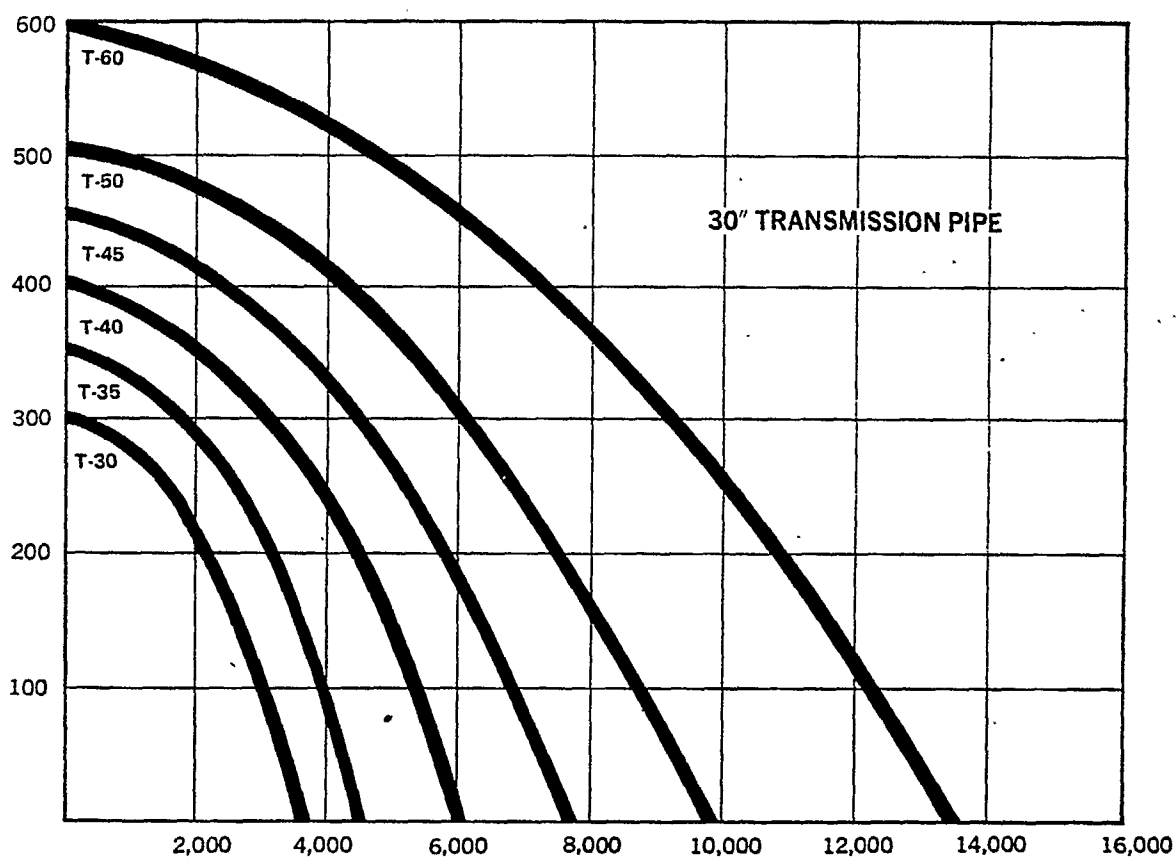
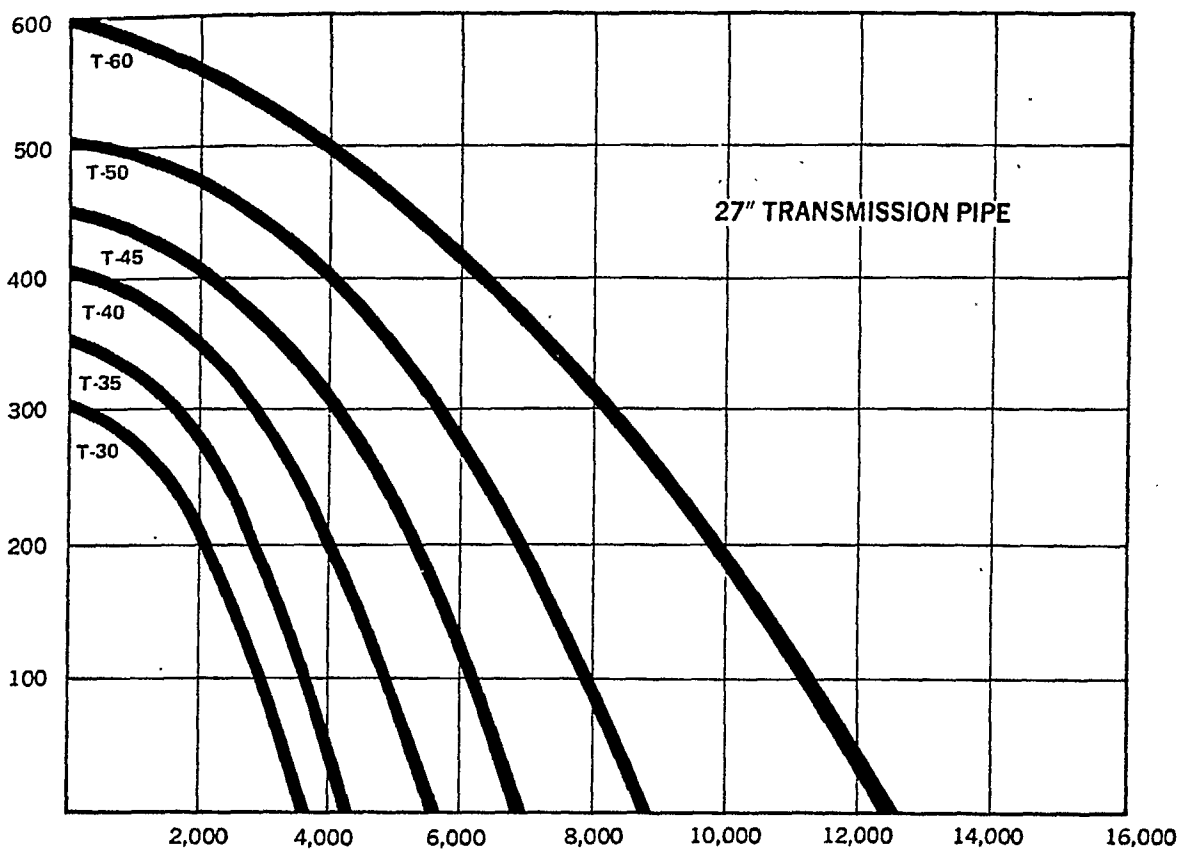
21" TRANSMISSION PIPE



24" TRANSMISSION PIPE



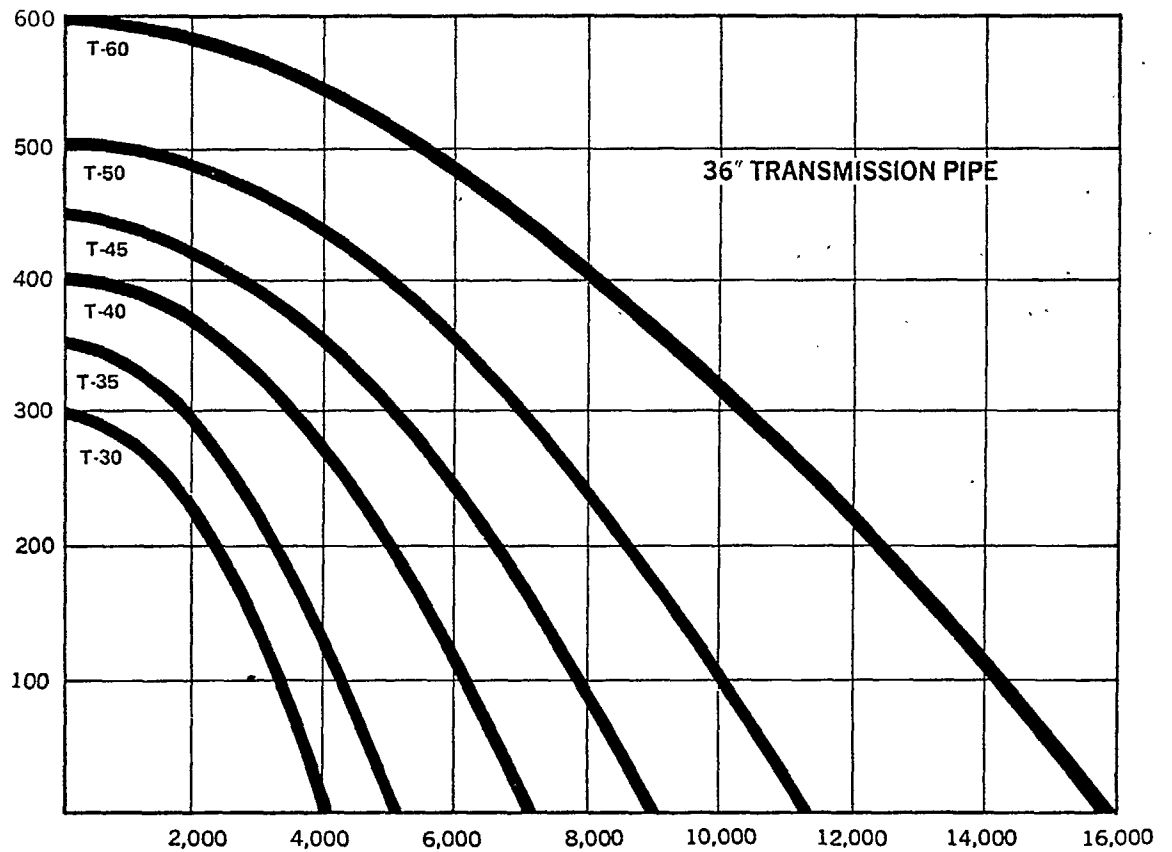
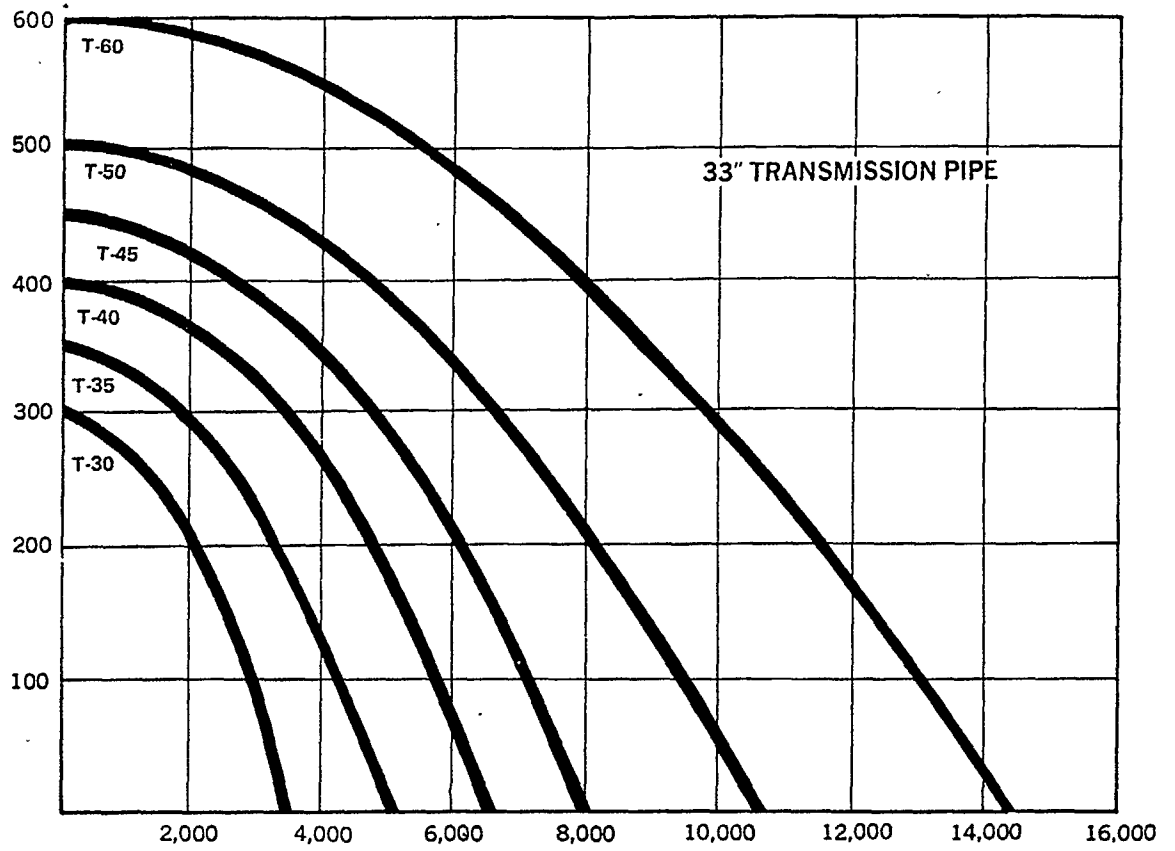
INTERNAL HYDROSTATIC DESIGN PRESSURE IN psi — p = (OPERATING PRESSURE + WATER HAMMER) SAFETY FACTOR



EXTERNAL CRUSH DESIGN LOAD (3-Edge Bearing) — W (lb/ft)

$$W = (\text{EARTH LOAD} + \text{LIVE LOAD}) \frac{\text{SAFETY FACTOR}}{\text{BEDDING FACTOR}}$$

INTERNAL HYDROSTATIC DESIGN PRESSURE IN psi — p = (OPERATING PRESSURE + WATER HAMMER) SAFETY FACTOR



EXTERNAL CRUSH DESIGN LOAD (3-Edge Bearing) — W (lb/ft)

$$W = (\text{EARTH LOAD} + \text{LIVE LOAD}) \frac{\text{SAFETY FACTOR}}{\text{BEDDING FACTOR}}$$

APPENDIX I

Illustrative Problems on Pipe Selection

PROBLEM 1

A 24" TRANSITE transmission line is to be installed in a 4 ft. wide trench with 5 feet of cover. The operating pressure will be 100 psi. Surge pressures will be limited to a maximum of 50 psi. A 10,000 lb wheel load is to be assumed with impact factor = 1. Class C bedding will be used. Select the proper strength of pipe to be used with a safety factor of 2.0 in hydro (OP + WH) and 1.5 in crush (EL + LL).

Solution:

Following instructions for use of selection charts with safety factors as suggested by J-M:

1. $OP + WH = 100 + 50 = 150$ psi
2. $EL + LL = 2030 + 400 = 2430$ lbs/ft (From tables in appendices C & D)
3. $(OP + WH) (SF) = 150 \times 2.0 = 300$ psi
4. $\frac{(EL + LL) (SF)}{BF} = \frac{2430 \times 1.5}{1.5} = 2430$ lbs/lin ft.
5. Enter combined loading chart for 24" pipe, using the left hand and bottom scales. Plot the two loads as a single point on the chart. The point falls between T-40 and T-50. Use T-50.

PROBLEM 2

Assume the same conditions as in Problem 1, but use safety factors of 2.5 in hydro (OP + WH) and 2.0 in crush (EL + LL).

Solution:

Follow instructions for use of selection charts with safety factors as selected by the designer.

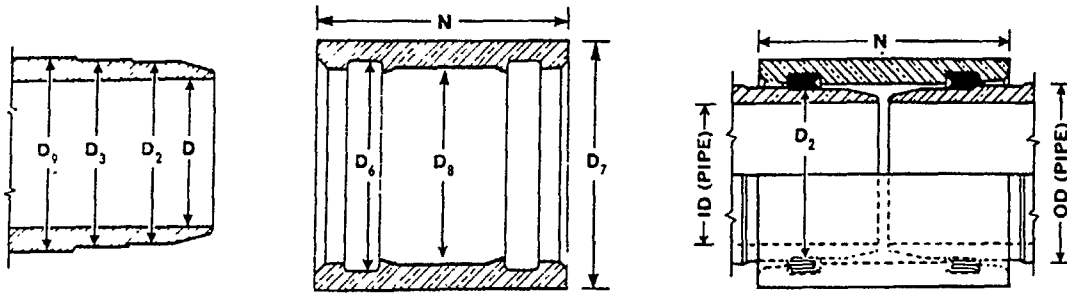
1. $OP + WH = 100 + 50 = 150$ psi
2. $EL + LL = 2030 + 400 = 2430$ lbs/ft.
3. $(OP + WH) (SF) = 150 \times 2.5 = 375$ psi
4. $\frac{(EL + LL) (SF)}{BF} = \frac{2430 \times 2.0}{1.5} = 3250$
5. Enter combined loading chart for 24" pipe, using left hand and bottom scales. Plot as one point the two values from steps 3 and 4. The point falls between T-40 and T-50. Use T-50.





APPENDIX J

Pipe and Coupling Dimensions and Weights



PIPE AND COUPLING DIMENSIONS (INCHES)								
T-30								
PIPE SIZE	D	D ₂	D ₃	D ₆	D ₇	D ₈	D ₉ *	N
18"	18.00	19.28	19.44	20.16	21.76	19.41	19.70	10.00
20"	20.00	21.44	21.60	22.32	24.14	21.57	21.86	10.00
21"	21.00	22.52	22.68	23.40	25.34	22.65	22.94	10.00
24"	24.00	25.76	25.92	26.64	28.90	25.89	26.18	10.00
27"	27.00	29.00	29.16	29.88	32.50	29.13	29.43	11.00
30"	30.00	32.24	32.40	33.12	36.10	32.37	32.67	11.00
33"	33.00	35.48	35.64	36.36	39.68	35.61	35.92	11.00
36"	36.00	38.72	38.88	39.60	43.24	38.85	39.16	11.00
T-35								
PIPE SIZE	D	D ₂	D ₃	D ₆	D ₇	D ₈	D ₉ *	N
18"	18.00	19.28	19.44	20.16	21.76	19.41	19.82	10.00
20"	20.00	21.44	21.60	22.32	24.14	21.57	22.05	10.00
21"	21.00	22.52	22.68	23.40	25.34	22.65	23.09	10.00
24"	24.00	25.76	25.92	26.64	28.90	25.89	26.31	10.00
27"	27.00	29.00	29.16	29.88	32.50	29.13	29.57	11.00
30"	30.00	32.24	32.40	33.12	36.10	32.37	32.83	11.00
33"	33.00	35.48	35.64	36.36	39.68	35.61	36.10	11.00
36"	36.00	38.72	38.88	39.60	43.24	38.85	39.36	11.00
T-40								
PIPE SIZE	D	D ₂	D ₃	D ₆	D ₇	D ₈	D ₉ *	N
18"	18.00	19.90	20.06	20.78	22.96	20.03	20.30	10.00
20"	20.00	22.12	22.28	23.00	25.46	22.25	22.52	10.00
21"	21.00	23.28	23.44	24.16	26.76	23.41	23.68	10.00
24"	24.00	26.48	26.64	27.36	30.36	26.61	26.88	10.00
27"	27.00	29.90	30.06	30.78	34.30	30.03	30.30	11.00
30"	30.00	33.12	33.28	34.00	37.92	33.25	33.54	11.00
33"	33.00	36.52	36.68	37.40	41.76	36.65	36.92	11.00
36"	36.00	39.78	39.94	40.66	45.44	39.91	40.18	11.00
T-45								
PIPE SIZE	D	D ₂	D ₃	D ₆	D ₇	D ₈	D ₉ *	N
18"	18.00	19.90	20.06	20.78	22.96	20.03	20.30	10.00
20"	20.00	22.12	22.28	23.00	25.46	22.25	22.52	10.00
21"	21.00	23.28	23.44	24.16	26.76	23.41	23.68	10.00
24"	24.00	26.48	26.64	27.36	30.36	26.61	26.88	10.00
27"	27.00	29.90	30.06	30.78	34.30	30.03	30.30	11.00
30"	30.00	33.12	33.28	34.00	37.92	33.25	33.54	11.00
33"	33.00	36.52	36.68	37.40	41.76	36.65	36.92	11.00
36"	36.00	39.78	39.94	40.66	45.44	39.91	40.22	11.00

*SUBJECT TO MANUFACTURING TOLERANCE.

PIPE AND COUPLING DIMENSIONS (INCHES)								
T-50								
PIPE SIZE	D	D ₂	D ₃	D ₆	D ₇	D ₈	D ₉ *	N
18"	18.00	19.90	20.06	20.78	22.96	20.03	20.35	10.00
20"	20.00	22.12	22.28	23.00	25.46	22.25	22.58	10.00
21"	21.00	23.28	23.44	24.16	26.76	23.41	23.71	10.00
24"	24.00	26.48	26.64	27.36	30.36	26.61	27.07	10.00
27"	27.00	29.90	30.06	30.78	34.30	30.03	30.46	11.00
30"	30.00	33.12	33.28	34.00	37.92	33.25	33.84	11.00
33"	33.00	36.52	36.68	37.40	41.76	36.65	37.22	11.00
36"	36.00	39.78	39.94	40.66	45.44	39.91	40.61	11.00
T-60								
PIPE SIZE	D	D ₂	D ₃	D ₆	D ₇	D ₈	D ₉ *	N
18"	18.00	20.50	20.66	21.38	24.36	20.63	20.81	10.00
20"	20.00	22.83	22.99	23.71	26.99	22.96	23.18	10.00
21"	21.00	23.96	24.12	24.84	28.34	24.09	24.27	10.00
24"	24.00	27.42	27.58	28.30	32.32	27.55	27.74	10.00
27"	27.00	30.89	31.05	31.77	36.39	31.02	31.21	11.00
30"	30.00	34.35	34.51	35.23	40.39	34.48	34.68	11.00
33"	33.00	37.74	37.90	38.62	44.28	37.87	38.15	11.00
36"	36.00	41.22	41.38	42.10	48.40	41.35	41.61	11.00
T-70								
PIPE SIZE	D	D ₂	D ₃	D ₆	D ₇	D ₈	D ₉ *	N
18"	18.00	20.94	21.10	21.82	25.50	21.07	21.32	10.00
20"	20.00	23.28	23.44	24.16	28.26	23.41	23.69	10.00
21"	21.00	24.38	24.54	25.26	29.56	24.51	24.88	10.00
24"	24.00	27.96	28.12	28.84	33.78	28.09	28.43	10.00
27"	27.00	31.44	31.60	32.32	38.02	31.57	31.99	11.00
30"	30.00	35.00	35.16	35.88	42.24	35.13	35.54	11.00
33"	33.00	38.46	38.62	39.34	46.32	38.59	39.09	11.00
36"	36.00	42.04	42.20	42.92	50.56	42.17	42.65	11.00

*SUBJECT TO MANUFACTURING TOLERANCE

WEIGHTS—LBS/FT (INCLUDING COUPLINGS)							
PIPE SIZE	T-30	T-35	T-40	T-45	T-50	T-60	T-70
18"	46.9	49.9	64.0	64.0	65.3	79.8	95.5
20"	56.9	62.1	77.8	77.8	79.5	99.9	117.7
21"	62.3	66.6	86.8	87.6	86.6	108.0	129.5
24"	79.9	84.1	106.6	106.6	112.9	140.8	168.9
27"	100.8	105.9	138.3	138.3	144.3	180.0	215.5
30"	123.1	129.5	164.7	164.7	177.1	221.9	264.8
33"	147.9	155.8	200.5	200.5	214.1	267.8	320.5
36"	174.4	184.0	233.2	235.6	254.5	318.5	381.8

APPENDIX K

System Specifications

MATERIAL SPECIFICATION TRANSITE TRANSMISSION PIPE

a. General

Asbestos-cement pipe shall be "T" pipe as manufactured by Johns-Manville. This pipe shall be manufactured and tested within the continental limits of the United States in accordance with the requirements of this specification.

The pipe denoted on the drawings and in the schedule of symbols has a corresponding classification in the following selection table. This classification establishes the minimum requirements for pipe to be used in the locations shown on the drawings.

b. Classification

Various classifications of asbestos-cement pipe are permitted to be used at certain locations, and are designated T-30, T-35, T-40, T-45, T-50 and T-60.

c. Basis of Acceptance

The acceptability of the pipe will be based on the results of the following tests performed by the manufacturer: hydrostatic routine, hydrostatic lot, crushing strength, and by inspection during or after manufacture.

Certification that the pipe meets the test requirements of these specifications may be required.

d. Materials

The asbestos-cement pipe shall be composed of an intimate mixture of Portland cement, silica, and asbestos fiber, and water, free from organic substances, with or without the addition of curing agents, and cured in such manner as will produce pipe meeting the requirements of these specifications.

e. Fabrication

The pipe shall be formed under pressure and thoroughly autoclaved.

f. Dimensions

1. SIZES. — The pipe may be furnished in sizes (internal diameter): 18, 20, 21, 24, 27, 30, 33, and 36 inches. 2. DIAMETER TOLERANCE. — The average internal diameter, measured 3 inches

from the end of the pipe, shall not vary from the manufacturer's standard, as approved, by more than 5 percent. 3. WALL THICKNESS. — The wall thickness at the machined portions of any pipe shall not be less than the manufacturer's standard as follows:

Size of Pipe	Wall Thickness Tolerance
18"	.12"
20"-24"	.14"
27"-30"	.17"
33"-36"	.20"

4. STRAIGHTNESS. — No pipe shall have a variance from straightness, measured as an outside middle ordinate, of more than 0.05 inches per foot of length.

g. Workmanship and Finish

The pipe shall be uniform in quality and shall be free from bulges, dents, fractures, and tears on the inside surface which result in a variation in diameter greater than 0.20 inch from that obtained on adjacent unaffected portions of the surface. The pipe shall also be free from excessive interior surface flaking and roughness. The machined ends of the pipe shall be free from dents and gouges which will affect the tightness of the joint.

h. Joints

The asbestos-cement pipe joint shall consist of two pipe spigots coupled with a collar and two rubber rings. The couplings shall be designed to permit joint flexibility and shall be grooved to receive the rubber rings and hold them in proper position. The spigot end shall be step machined to close tolerance to provide the proper pressure on the rubber ring and shall have a shoulder to automatically position the pipe in the coupling to leave sufficient space for the pipe to expand upon wetting and for maintaining end clearance when deflected as outlined in the installation specification. The rubber ring shall be of uniform solid cross-section and shall conform to the latest revision of ASTM Specification D-1869 entitled "Rubber Rings for Asbestos-Cement Pipe."

i. Routine Hydrostatic Test

Each pipe unit and each coupling shall withstand routine hydrostatic test load of not less than the pressure designated in the table shown.

The routine hydrostatic test shall be conducted by placing the pipe in a hydrostatic pressure testing machine with gaskets which seal the ends of the pipe. Couplings may be tested with the pipe as described above or standard couplings may be tested with a rubber bladder inside of the coupling and, if so tested, each coupling shall have sufficient strength to withstand a hydrostatic test of one and one-half times the head designated in the table shown, or 800 lbs., whichever is lower. Routine hydrostatic tests will not be required on A/C tapers or heavy tapped couplings and all such fittings will be manufactured of the same material and by the same method as used in manufacturing the pipe that is tested.

j. Lot Hydrostatic Test

One 1-foot unmachined section or longer out of every lot of 300 shall withstand a hydrostatic test of not less than the pressure designated in the table shown. Tests will be performed as described in the previous section (i).

In the event that a test specimen fails to withstand the lot hydrostatic test, the manufacturer will be allowed to test two additional specimens of the

same size and class manufactured during the same shift. If either of the two additional specimens fail to pass the test, the entire lot of pipe represented by the test specimen shall be rejected.

k. Crushing Strength Test

One-foot lengths of pipe cut from unmachined portions of the pipe shall withstand the minimum crushing strength prescribed below. A 12-inch long test specimen shall be cut from a standard pipe unit selected from each 300 lengths of each size and classification of pipe and tested in accordance with ASTM Specification C-500.

In the event that a test specimen fails to withstand the crushing strength test the manufacturer will be allowed to test two additional specimens of the same size and class manufactured during the same shift. If either of the two additional specimens fail to pass the test, the entire lot of pipe represented by the test specimen shall be rejected.

l. Chemical Stability

To assure chemical stability, the pipe shall not have an uncombined calcium hydroxide content in excess of 1% when tested in accordance with the method outlined in ASTM Specification C-500.

m. Marking

Each standard and random length of pipe shall be marked with the size and classification of pipe, name of manufacturer or trademark, and the date of manufacture.

ROUTINE HYDROSTATIC TEST LOADS (PSI)							
	T-30	T-35	T-40	T-45	T-50	T-60	T-70
ALL SIZES	225	263	300	338	375	450	525

LOT HYDROSTATIC TEST LOADS (PSI)							
	T-30	T-35	T-40	T-45	T-50	T-60	T-70
ALL SIZES	300	350	400	450	500	600	700

CRUSHING TEST LOADS (LBS/LIN FT)							
PIPE SIZES	T-30	T-35	T-40	T-45	T-50	T-60	T-70
18"	2500	3000	4000	5000	6500	8500	11000
20"	2500	3500	4500	5500	7100	9500	12000
21"	2500	3500	4500	5800	7300	9700	12500
24"	2800	3800	5000	6200	8100	11000	15000
27"	3500	4200	5500	7000	8800	12500	16500
30"	3500	4500	6000	7500	9700	13500	18000
33"	3500	5000	6500	8000	10500	14500	19500
36"	4000	5000	7000	9000	11200	16000	21000

INSTALLATION SPECIFICATIONS TRANSITE TRANSMISSION PIPE

a. Installing

All asbestos cement pipe shall be laid in accordance with AWWA specification C603 with the following additions and clarifications:

Asbestos cement pipe, including fittings, shall be laid to the lines and grades shown in the drawings. Departure and return to established alignment and grade shall not exceed 1/16 inch per foot with a total of not more than one inch departure.

The joining of pipe sections shall be such as to produce water tight lines for the conveyance of water. In all cases every field joint shall be checked with a feeler gauge for proper ring position. The pipe trenches shall be kept free of water which might impair pipe joining operations.

The methods of lowering the pipe into the trench and placing in position shall be such as to prevent getting dirt inside of the pipe and coupling and to prevent damage to the pipe. Before and during assembly of the joint all parts shall be clean and shall be free of mud, ice, oil, or grease. The use of non-toxic water-soluble lubricant will be permitted for making the joint assembly. In positioning the pipe, the pipe shall be aligned straight, with ends squared, and the joint closed to properly position the gasket. The pipe shall be maintained firmly in final position.

The pipe shall be laid in a trench conforming to the Contract Drawings and Specifications.

In all bedding conditions, care shall be taken, so that coupling sleeves will not come in contact with the trench subgrade.

The compaction of the backfill shall be as directed by the engineer. Tamping or flooding may be accomplished as approved by the engineer.

b. Curves and Bends

Changes in alignment and grade shall be made by deflecting the pipe units at joints. Pipe units shorter than standard length may be required. The maximum deflection angle between adjacent pipe units in place shall not exceed $3\frac{1}{2}^\circ$ for 18" through 24" diameter size and 3° for 30" diameter and larger sizes. These deflections apply to couplings belled on the job site. For factory

belled couplings, use $\frac{1}{2}$ of the above deflections. The ends of each pipe unit shall be laid on the theoretical centerline of the pipeline and to the grade shown on the drawings.

c. Testing

All piping shall be subjected to a hydrostatic pressure test. Prior to testing, each section of asbestos cement pipe shall be partially backfilled to prevent movement.

The test pressure shall be the operating pressure plus 50 psi, or the total of the operating pressure plus surge allowance, whichever is greater, as defined by the engineer.

Tests on asbestos cement pipe shall not be applied until the main has been filled with water for a minimum of twenty four hours.

This test shall be performed on all sections of the water main so that all pipe, valves, fittings, fire hydrants, connections and water services are subject to the test. The test pressure shall be maintained continuously by pumping for a period of at least one hour. At the end of the first hour the pressure shall meet the requirements stated above. Pumping shall then be discontinued for one hour and the drop in pressure read on the dial of the gauge at the end of the second hour and recorded. The initial test pressure shall then be restored by pumping and the quantity of water pumped into the line to accomplish this shall be measured accurately. This quantity shall not exceed the amount shown in the table on the next page. If there is any sign of failure at any point on the line during the test, the test shall be discontinued until the same has been repaired, after which the test shall be repeated until the section tested shall have met the above requirements. The test shall be performed and accepted only in the presence of the engineer or his designated representative.

The contractor shall furnish and install, at his own expense, all corporation stops, temporary pipe, fittings, connections, equipment, bulkheads and bracing required for the tests, and he shall be responsible for any and all damages resulting from failure under test of material furnished and installed by him or from faulty workmanship, negligence or improper test methods.

DISPLACEMENT ALLOWANCE* — Gallons Per 100 Couplings Per Hour							
PIPE SIZE	TEST PRESSURE (PSI)						
	50	75	100	125	150	200	225
18"	3.18	3.87	4.52	5.02	5.52	6.37	6.75
20"	3.54	4.30	5.00	5.58	6.12	7.08	7.51
24"	4.24	5.16	6.00	6.69	7.34	8.50	9.01
30"	5.30	6.45	7.51	8.37	9.18	10.62	11.26
36"	6.37	7.75	9.01	10.07	11.02	12.74	13.50
*Evaluated on basis of 150 psi, this is approximately equal to 30 U. S. gallons, per 24 hours, per mile of pipe, per inch of pipe diameter for pipe in 13-foot lengths. To determine total loss for a given length of pipe line;— against pipe size and under test pressure, find gallons per 100 couplings per hour. Multiply this by actual number of couplings (each fitting bell equals one half coupling) and then by hours of test duration: For example, one mile of 20" pipe at 150 lbs. for 2 hours = 6.12 gals. per 100 couplings per hour. Since there are about 407 couplings per mile, multiply 6.12 by 4.07 giving 24.91 gals. per hour, times 2 = 49.82 gals. allowable leakage in 2 hours.							

APPENDIX L

Thrust Control

Requirements for thrust control are normally indicated by the engineer. Location, size and type are his responsibility and should be included in his specifications.

When Used

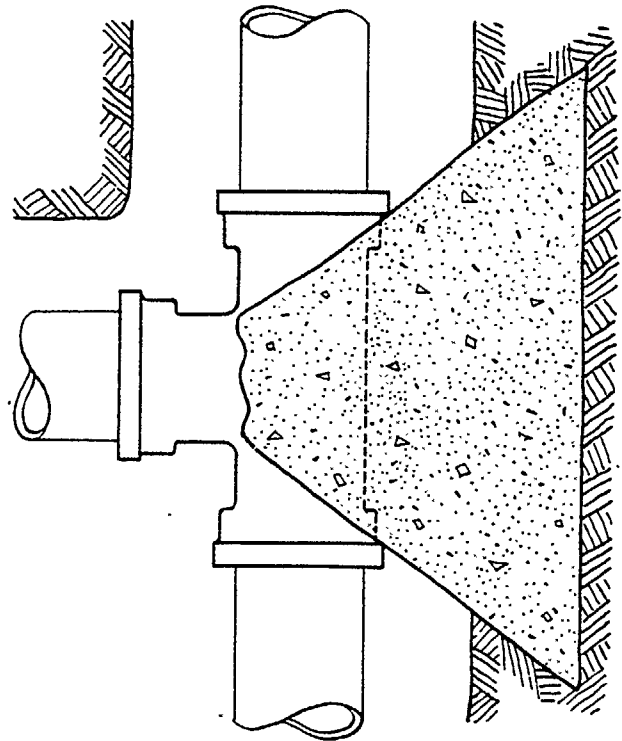
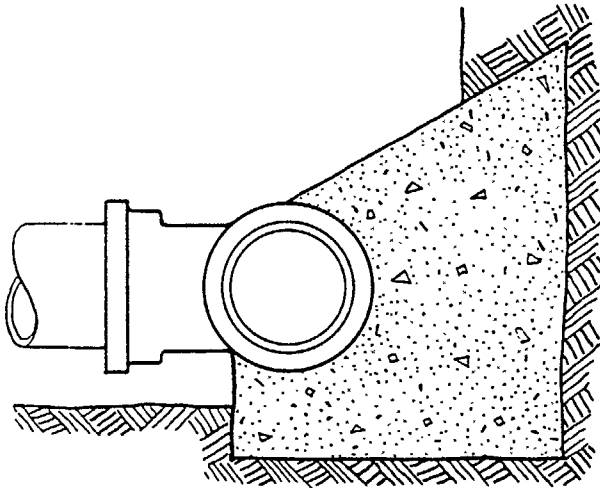
Thrust control is necessary wherever the pipeline — changes direction, as at tees and bends; changes sizes, as at reducers; stops, as at a dead end; or is expected to develop thrusts at valves.

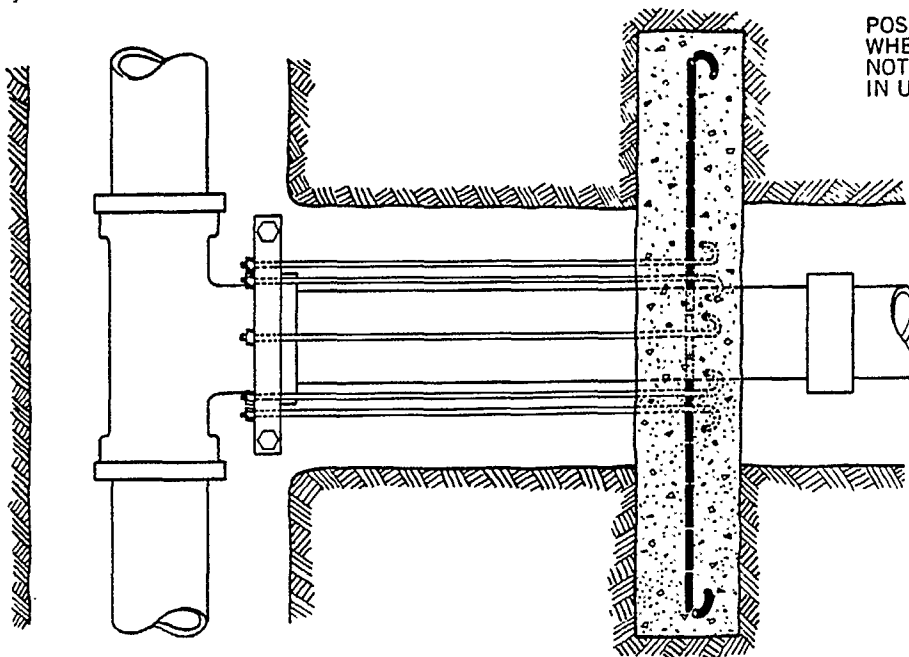
Size and Type

The size and type of thrust control depends on pressure, pipe size, kind of soil and the type of fitting.

Following are sketches of a few methods used to control thrust. They are offered as suggestions only. The actual design of thrust control is normally the responsibility of the engineer. In unusual conditions consult a soils engineer for economical thrust control designs.

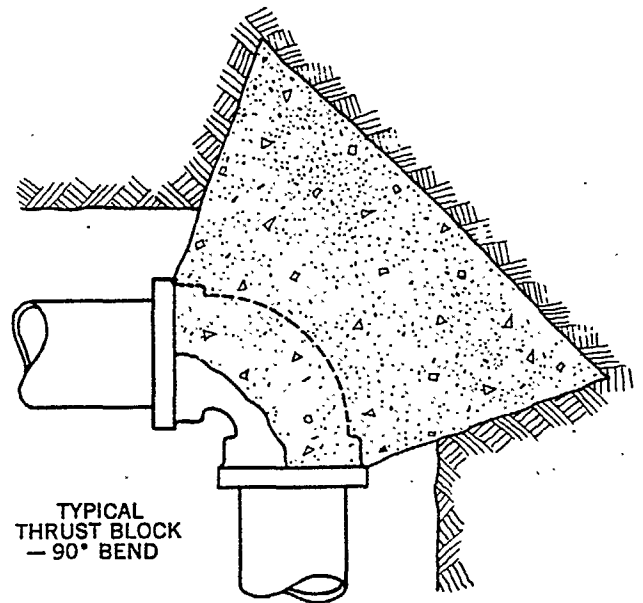
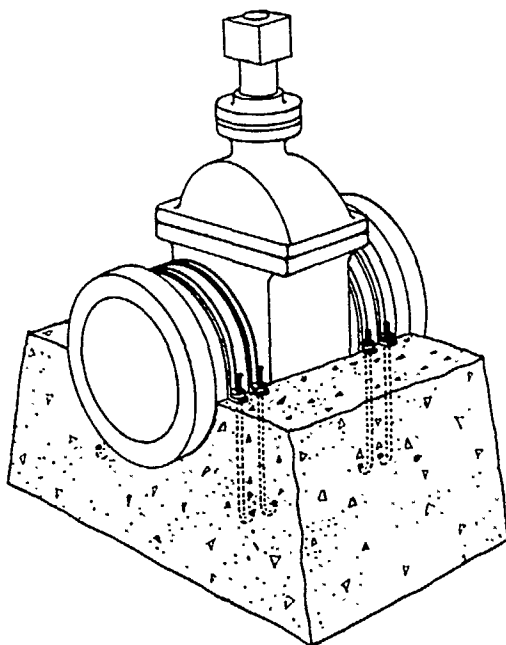
TYPICAL THRUST BLOCK — TEE



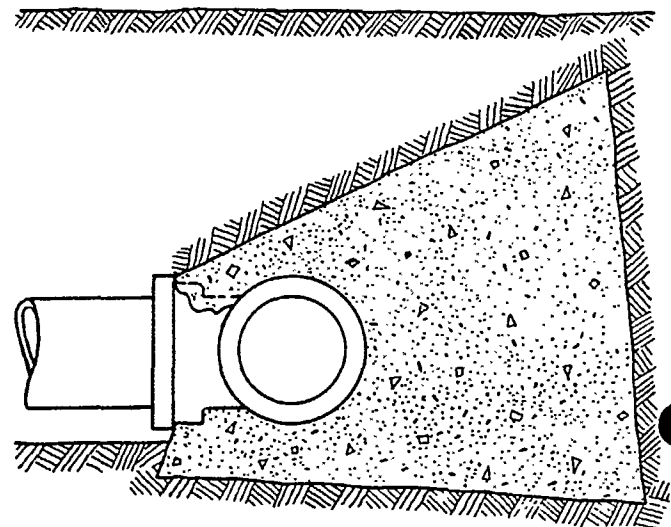


POSSIBLE THRUST CONTROL
WHERE THRUST BLOCK AREA
NOT AVAILABLE OR
IN UNSTABLE SOIL.

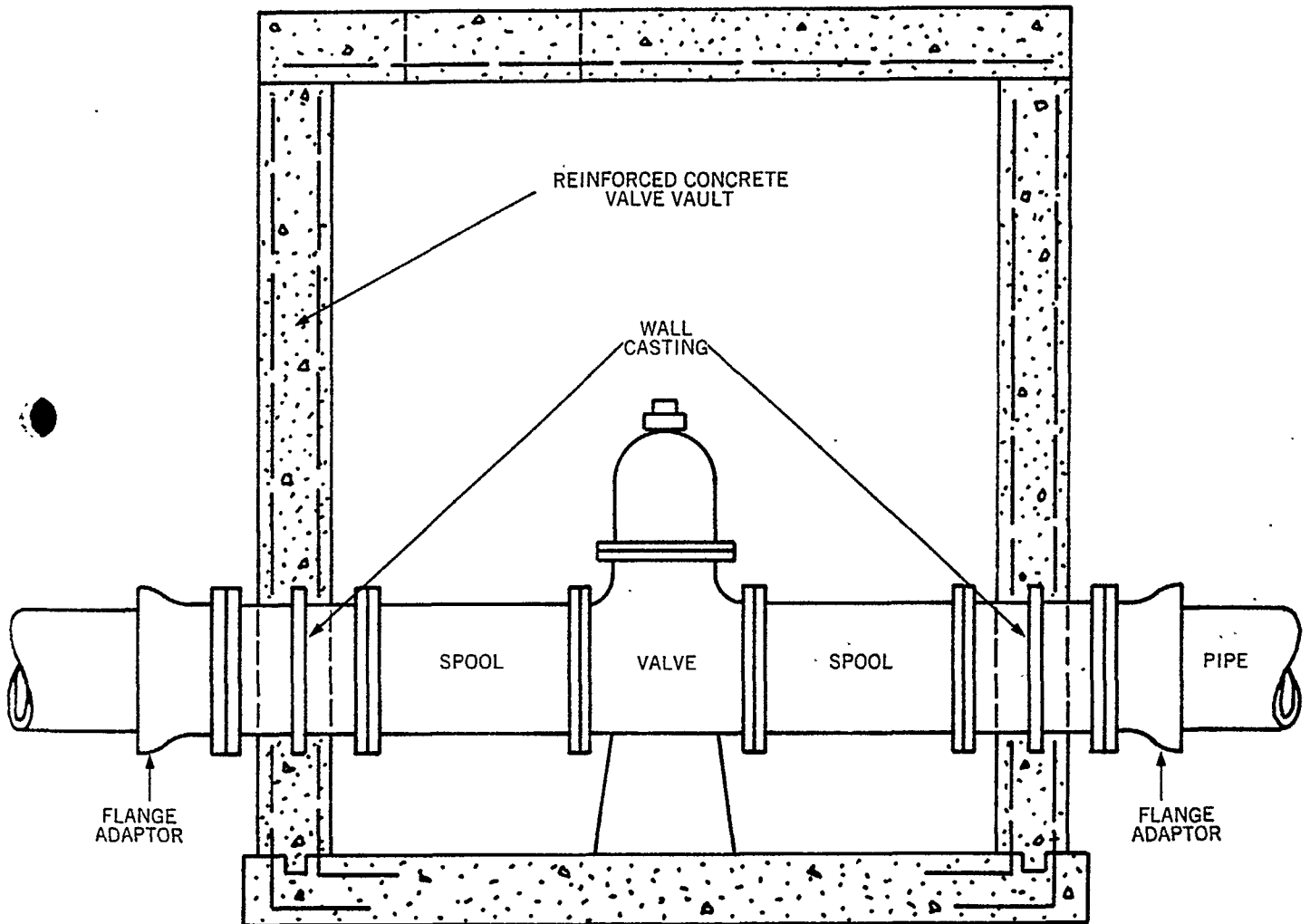
TYPICAL
THRUST BLOCK
— VALVE



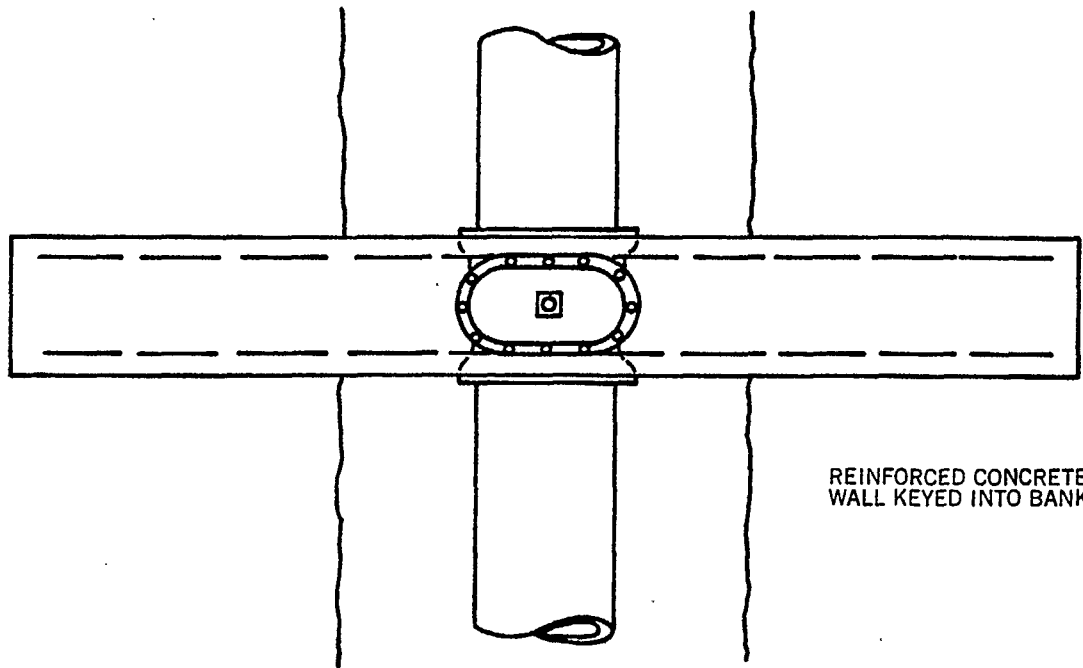
TYPICAL
THRUST BLOCK
— 90° BEND



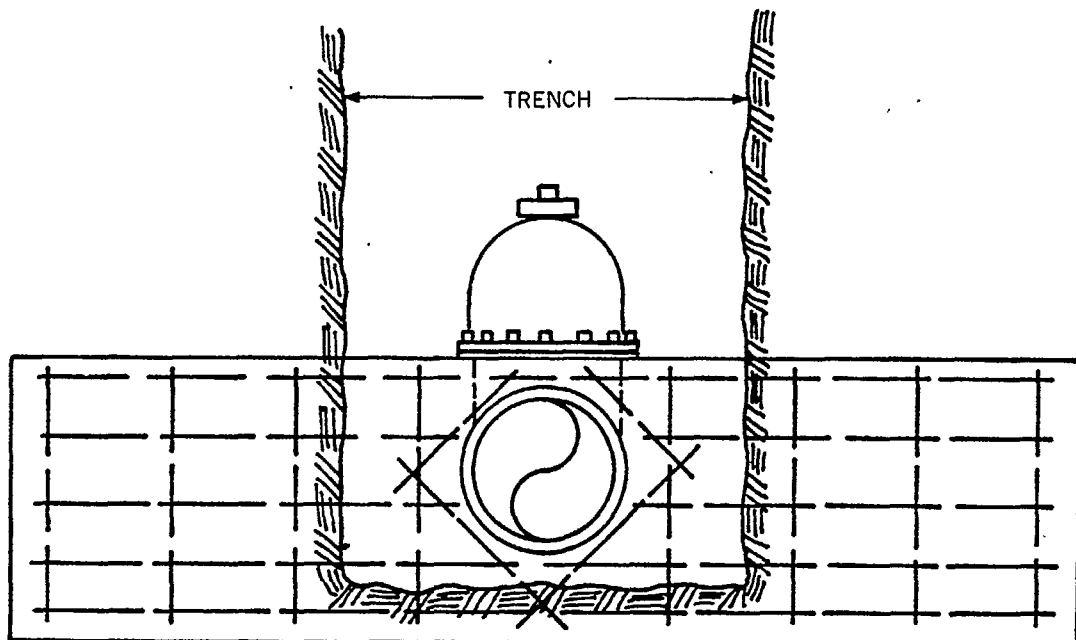
Valve Anchor in Vault



Valve Anchor

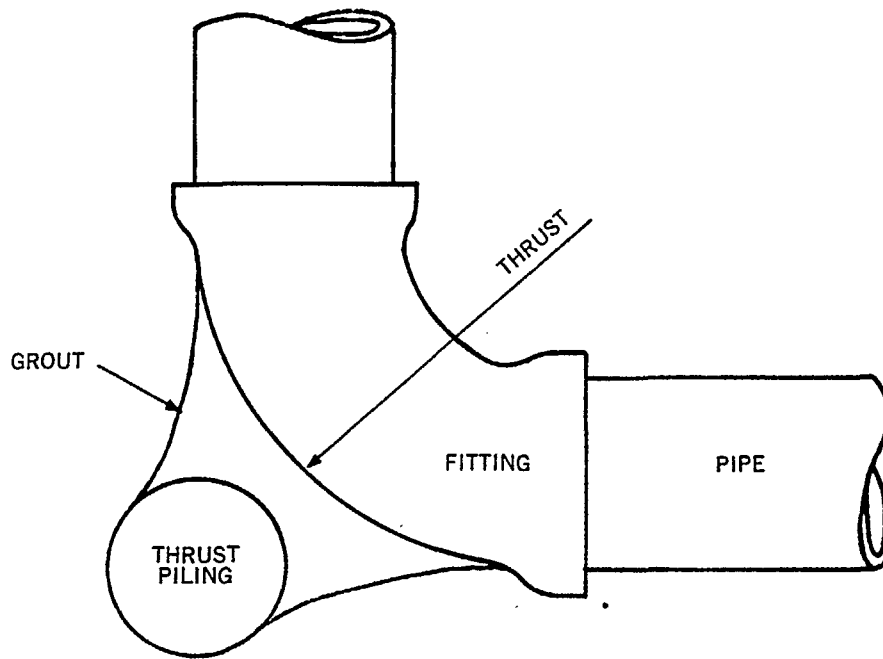


PLAN

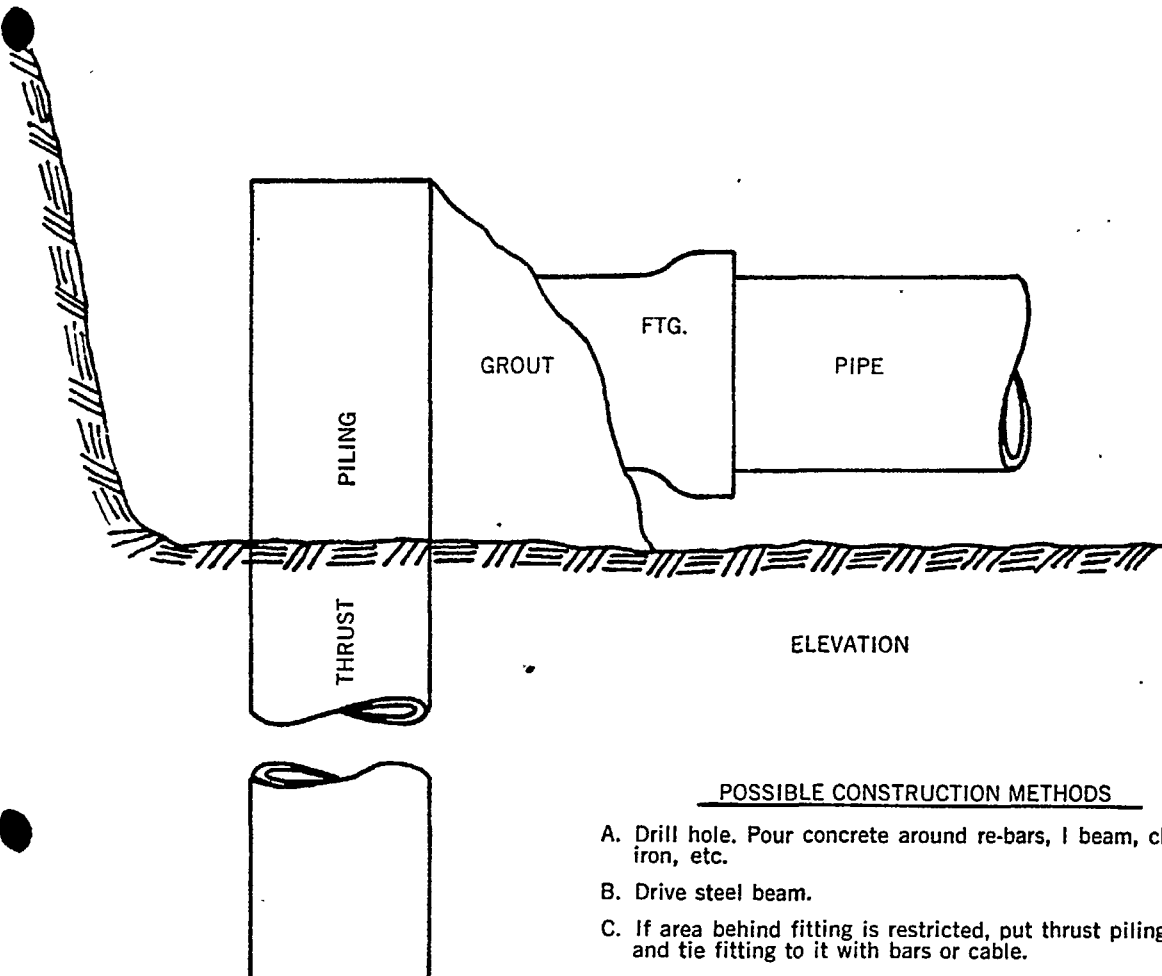


ELEVATION

Thrust Piling



PLAN



ELEVATION

POSSIBLE CONSTRUCTION METHODS

- A. Drill hole. Pour concrete around re-bars, I beam, channel iron, etc.
- B. Drive steel beam.
- C. If area behind fitting is restricted, put thrust piling in front and tie fitting to it with bars or cable.



APPENDIX M

Reducers and Adaptors

Johns-Manville makes available a number of asbestos-cement accessories for use with TRANSITE Transmission Pipe.

a. Reducers

When connecting one size of pipe with the next lower size pipe, a reducer is required. The reducer is designed so that the outside fits into the coupling of the larger size. The end of the lower size pipe fits into the reducer. The reducer is tapered so that the flow is directed from the larger to the smaller pipe.

b. Classification to Classification Adaptor

For the same size pipe, where it is necessary to connect two different classifications of pipe in a run and where the end machining is not the same, an adaptor is required. One end is machined to receive the coupling of the lower classification pipe and the other end is machined to receive the higher classification pipe.

c. Heavy Bushed Couplings

For each size pipe, a thick wall coupling is available

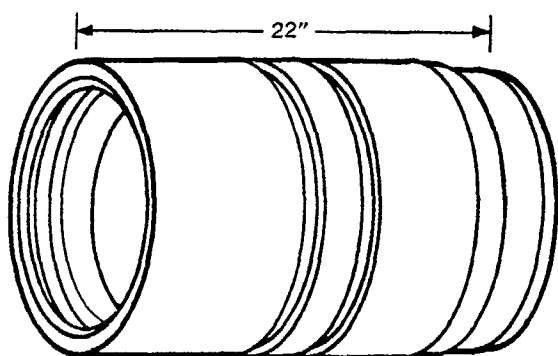
with a 2" bushed outlet. The outlet is available with galvanized or brass, with an iron pipe thread only.

d. C.I. Mechanical Joint Adaptor

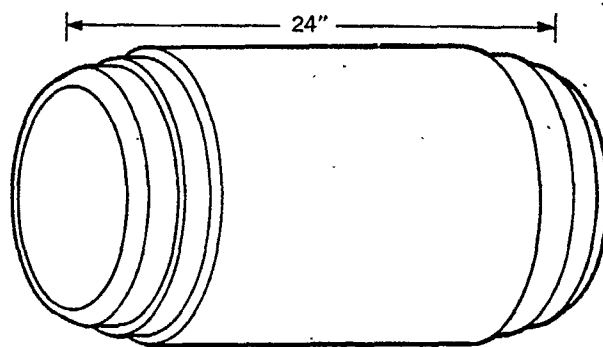
When connecting TRANSITE pipe to C.I. M.J. fittings, an adaptor is required. One end of the adaptor is C.I. O.D.; the other end is "T" Pipe dimension (D2). The I.D. of M.J. adaptor will be somewhat less than the pipe I.D. M.J. adaptors for butterfly valves must be bevelled on the I.D. at the M.J. end.

e. Short Lengths

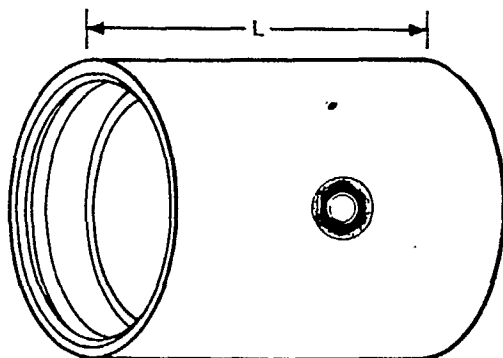
Short lengths (6'-6" long) are available machined each end (MEE) and also machined over-all (MOA). In some sizes and classes the MOA pieces will have a reduced I.D. For making closures the MOA piece is cut to length and two couplings are pushed onto the ends. Next the MOA is dropped into position. Each coupling is then pulled back and centered over the joint.



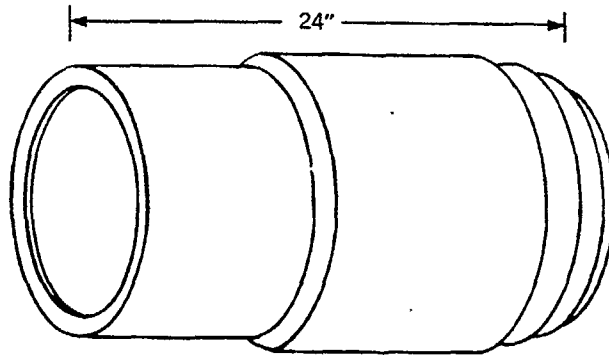
a. Reducer



b. Classification to Classification Adaptor



c. Heavy Bushed Coupling
(2" IPT Outlet)



d. C.I. Mechanical Joint Adaptor

APPENDIX N

Technical Advice

Any technical advice which appears in any Johns-Manville literature or which is furnished by a Johns-Manville representative with reference to the use of Johns-Manville products is furnished

gratis. It is solely for evaluation by the purchaser for use or non-use as the purchaser sees fit. Johns-Manville assumes no obligation or liability for such advice or any results obtained.

The physical (or chemical) properties of Johns-Manville TRANSITE Transmission Pipe and Fittings represent typical, average values obtained in accordance with accepted test methods and are subject to normal manufacturing variations. The indicated minimum values are as shown. This information is supplied as a technical service and is subject to change without notice. Check the Johns-Manville Customer Service Center or Local Representative to assure current information.

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All products sold are subject to the following warranty: J-M warrants for a period of one year from date of delivery to the original retail purchaser that the Product is free from defects in materials and workmanship. **J-M MAKES NO OTHER REPRESENTATION OR WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, IN FACT OR IN LAW, INCLUDING WITHOUT LIMITATION, THE WARRANTY OF MERCHANTABILITY OR THE WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE.** The limit of J-M's liability for failure of its Product to meet the foregoing warranty shall be, at J-M's sole option, repair or replacement of the defective Product and shall exclude any damage caused by accident, misuse, or abuse of the Product. **IN NO EVENT SHALL J-M BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES.**

For Information on other J-M Products and Systems call Product Information Center at (303) 770-1000 Ext. 2745



APPENDIX O

References

"AWWA Standard for Asbestos-Cement Transmission Pipe, 18 in. through 42 in., for Water and Other Liquids," AWWA C402.

"Standard Practice for the Selection of Asbestos-Cement Water Pipe," AWWA C401.

"TRANSITE Transmission Pipe Installation Guide," Johns-Manville Corp., 1971.

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Marston, Anson, "The Theory of External Loads on Closed Conduits in the Light of Latest Experiments," Iowa State College Eng. Exp. Sta. Bull. #96 (1930)

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"Standard Specification for Asbestos-Cement Transmission Pipe," ASTM Designation C668.

"Standard Methods of Testing Asbestos-Cement Pipe," ASTM Designation C500.



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NOTES

p. 12 - diagram how Transite pipe is
made