Flow Resistance of Asbestos-Cement Pipelines

By D. N. Foster, B.E., M.I.E.Aust.*

Summary.—Field and laboratory tests have been undertaken to study flow resistance of asbestos-cement pipelines ranging in size from 2¼-in. to 21-in. diameter. The exponential formula proposed by Vallentine (Ref. 2) from laboratory tests on a 4-in. line is shown to apply to pipelines of other diameters. This formula forms the basis of the design charts prepared by the manufacturers, James Hardie and Coy. Pty. Limited. Field tests indicate that under conditions normally encountered in water-supply systems the friction gradients given by the design charts should be increased by about 5 to 10%. Tests on a 15-in. pipeline installed in 1960 and a 21-in. pipeline installed in 1967 indicate that where the water is chlorinated there is only a small increase in friction loss as a result of ageing.

INTRODUCTION

Recent years have seen an increasing use of asbestos-cement pipelines in water supply, irrigation and sewerage schemes. Despite this, little information has been published on the friction characteristics of asbestos-cement pipelines under field conditions.

The purpose of this investigation was to determine by both laboratory and field measurements the friction characteristics of flow through asbestos-cement pipes and to compare performance in the new condition with performance after years of service.

Head Loss Equation:

Rational approaches to friction losses in pipes have most often been based on the Darcy-Weisbach relationship

$$h_L = f\frac{L}{D}\frac{V^2}{2g} \qquad \text{.............................(1)}$$

This equation has the advantages that it is dimensionally consistent and applies over a wider range than most of the exponential formulae that have been developed.

For the range of flow velocities and pipe sizes encountered in engineering practice, Vallentine (Ref. 2) has shown that flow in new asbestos-cement pipes is in the transitional turbulent region where both the Reynolds number of the flow and the roughness of the pipe surface affect the friction factor in the Darcy-Weisbach equation. Within this region the equation derived by Colebrook and White from tests on commercial pipes

$$\frac{1}{\sqrt{f}} = -2\log\left(\frac{k}{3.7D} + \frac{2.51}{R\sqrt{f}}\right) \qquad \text{.................(2)}$$

is generally regarded as the most accurate basis for hydraulic design.

Equivalent Roughness:

To simplify the use of the Colebrook-White equation, a number of charts have been prepared such as those of Moody. Rouse and Wallingford.

The use of these charts, or the Colebrook-White equation, requires an estimate of the equivalent roughness k on which little information has been published. Vallentine (Ref. 2) from laboratory tests on a straight 4-in. line, 92 ft. long, arrived at a value of $k = 0.00005$ ft. This value corresponds exactly with that recommended for use with the Wallingford charts (Ackers, Ref. 1) although the details on which the latter are based are not known.

It should be noted that the form losses at the pipe joints are incorporated in the value of k.

Design Charts:

On the basis of an equivalent roughness of 0.00005 ft., Vallentine (Ref. 2) has shown that flow of water at 60°F. through asbestos-cement pipes can be described by the exponential equation first proposed by Professor Ludin

$$Q = 2.80\,D^{2.65}\,H^{0.54} \qquad \text{.......................(3)}$$

where Q is flow rate in g.p.m., D is the pipe diameter in inches, H is the head loss in feet per 100 ft. of pipe length.

Within the velocity range 1 to 12 ft. /sec. and pipe diameters 2 to 24 in., head loss predicted by Eq. (3) agrees to within 4% with that obtained from the Colebrook-White equation.

Vallentine (Ref. 2) has prepared a flow resistance chart based on Eq. (3) which is currently recommended by the manufacturers, James Hardie and Coy. Pty. Limited, for the design of asbestos-cement pipelines.

Limitation of the Design Chart:

The general use of the experimental value of equivalent pipe roughness as obtained by Vallentine has been criticised on the following counts:

(i) Joint loss may not scale up in the same manner as surface friction loss. Since all pipe lengths are nominally 13 ft. the effective number of joints is increased as the pipe diameter is increased. Opposed to this the surface disturbance at the joint is smaller with increasing diameter tending to offset the above factor.

(ii) The laboratory tests were conducted on straight pipe lengths and take no account of small displacements and deflections which occur during the laying of the pipes.

(iii) No account is taken of the possible increase in friction with age resulting from organic growth, or the collection of slime on the walls of the pipe.

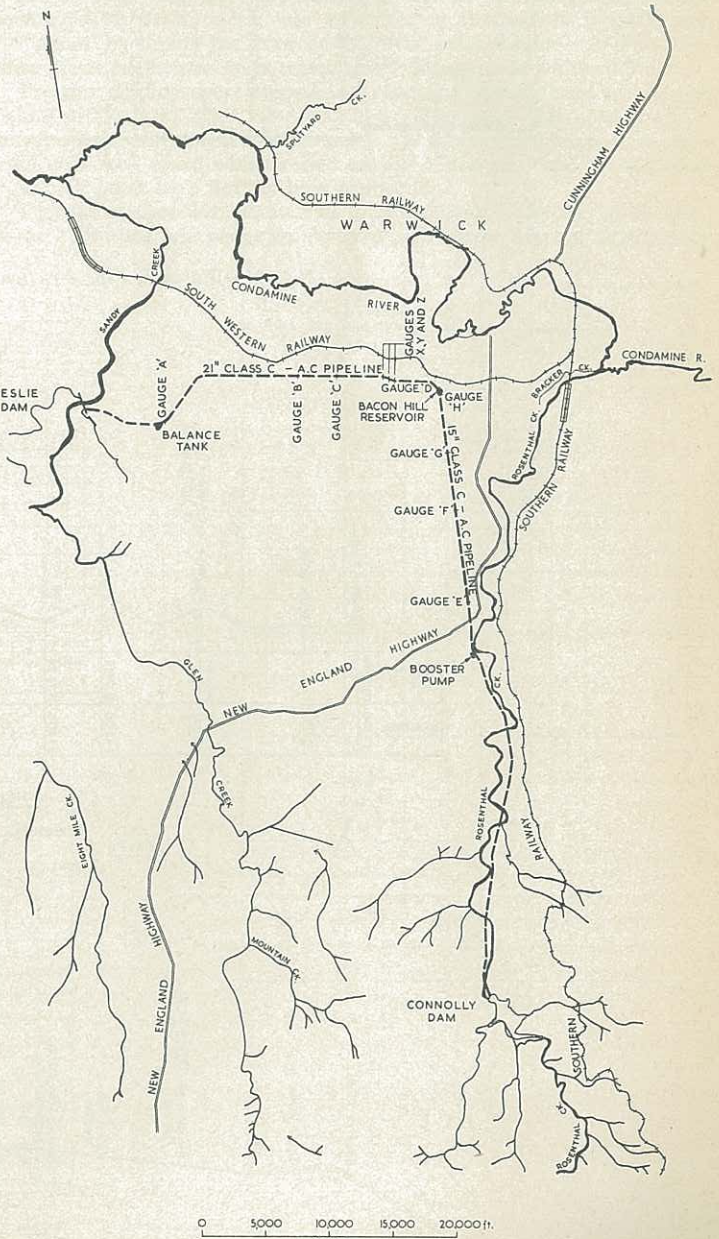

Fig. 1.—Warwick Pipe Friction Tests—Locality Plan.

---

*Paper No. 2602 presented at the Third Australasian Conference on Hydraulics and Fluid Mechanics held in Sydney from 25th to 29th November, 1968.

The author is a Senior Lecturer with the School of Civil Engineering, University of New South Wales.

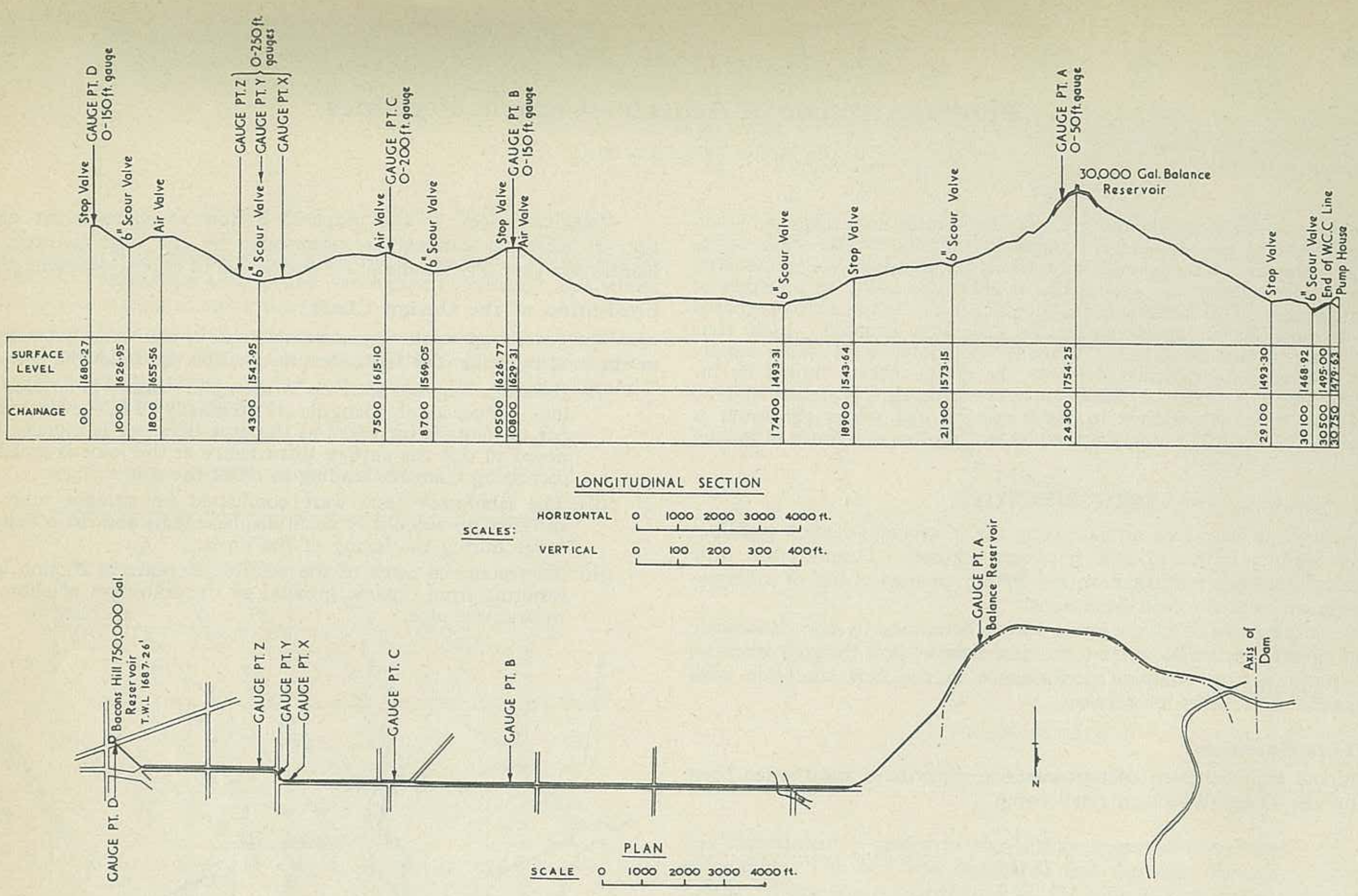

Fig. 2.—Warwick Pipe Friction Tests—Pipe Details—21-in. Pipeline.

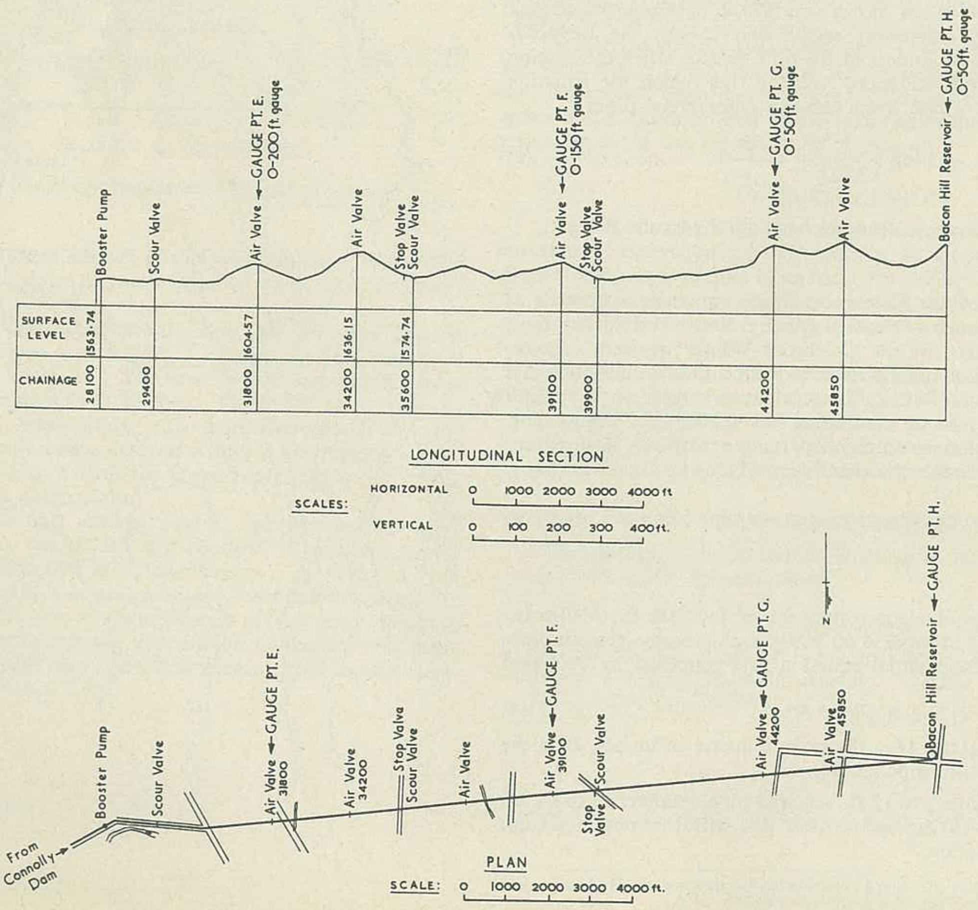

Fig. 3.—Warwick Pipe Friction Tests—Pipe Details—15-in. Pipeline.

Because of these doubts, laboratory and field studies have been undertaken to check the application of Eq. (3) and the flow chart over a range of pipe sizes.

LABORATORY TESTS

Friction tests were undertaken on new 2¼-in., 4-in. and 8-in. (nominal) dia. asbestos-cement pipelines. Water manometers connected to piezometer tappings drilled through the wall of the pipe, were used for measuring pressure at several locations along the pipe length. The pressure tappings were carefully drilled from the inside of the pipe to prevent chipping of the asbestos surface. A British Standard 1042 orifice meter was used for flow measurement.

During the tests on the 2¼-in. and 4-in. pipelines, the joint spacing was varied to study the effect of this factor on friction loss.

Details of test conditions and pipe sizes are shown in Table I.

TABLE I

Test Conditions for Laboratory Studies

Test Series	Nominal Pipe Size	Mean Pipe Dia. (in.)	Maximum Deviation in Dia. (in.)	Joint Spacing (in.)	Test Length (ft.)	Velocity Range (ft./sec.)	Water Temp. (°F.)
2A	2¼	2.250	0.015	Tight	65	3.8-11.8	53.5
2B				0.156		4.0-11.9	55.0
2C				0.374		3.9-11.6	54.0
4A	4AB	3.930	0.011	Tight	65	5.4-16.5	72.0
4B				0.374		5.8-16.5	71.0
4C				0.708		6.2-16.5	72.0
8A	8B	7.970	0.009	Random	104	1.1- 7.9	70.0
8B	8C	7.720	0.010	Random	65	3.0- 9.9	61.0

Experimental points, adjusted to a temperature of 60°F. (Vallentine, Ref. 2) are plotted in Fig. 4. Good agreement with the exponential formula (Eq. 3) shown as the full line on Fig. 4, was obtained for all pipe sizes. No effect of joint spacing could be detected from the tests.

FIELD TESTS

Field friction tests were undertaken on a 15-in. and 21-in. bitumen-covered, Class C, 'Supertite' coupling, asbestos-cement water-supply pipeline at Warwick, Queensland. A locality plan is shown in Fig. 1. The pipelines bring water from the Connolly and Leslie Dams to the Bacon Hill storage reservoir from where it is fed into the town distribution system. The water is chlorinated at an average dose rate of approximately 4 p.p.m.

Water from the Leslie Dam is pumped up to an open 22-ft. dia. balance reservoir from where it gravitates through a 21-in. main to the 100-ft. dia. Bacon Hill service reservoir. The total capacity of the three pumps provided is 3,000 g.p.m.

The 15-in. line gravitates water from Connolly Dam to Bacon Hill Reservoir and has a maximum capacity of approximately 1,000 g.p.m. This can be increased, if necessary, to about 1,400 g.p.m. by a booster pump installed mid-way along the pipeline.

Plans and elevations of the two pipelines are shown in Figs. 2 and 3. The 15-in. line was brought into service in 1960 and the 21-in. line in 1967. The water supply through both lines is chlorinated. The only draw-off from the two lines is a small number of irrigation offtakes and these were isolated during the tests.

Discharge measurements were by " Kent " flow meters and differential manometers connected to orifice meters installed in the pipelines. The 15-in. meter was calibrated at flow rates af 980 and 1,370 g.p.m. by timing the rise of water level over approximately 3 ft. in the Bacon Hill storage reservoir. The 21-in. meter was calibrated at flows of 880, 1,876 and 2,797 g.p.m. by timing the draw-down in the balance tank over 7 to 9 ft. Orifice meter coefficients so obtained gave agreement to within 0.2%.

Pressure tappings were prepared by placing a tapping band around the pipeline with a ½-in. gate valve attached. The valve was opened and a ¼-in. dia. hole drilled through the pipe. The pressure gauges were supported on a steel stand which rested on top of the pipe and connected to the tapping point by a flexible hose connection.

Pressure gauges were located at four positions along the 15-in. line. For the 21-in. line four gauge points were used for the first test programme

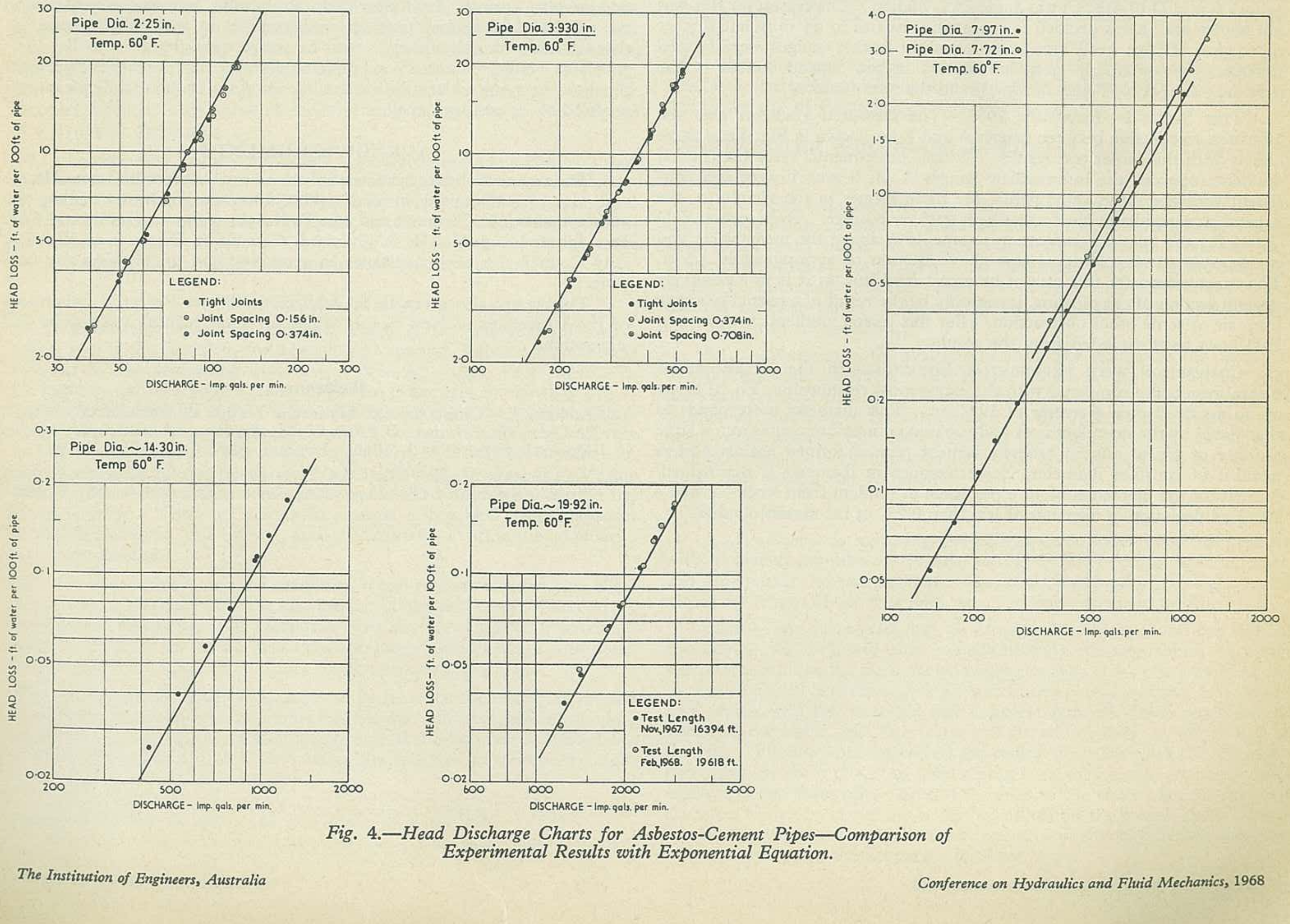

Fig. 4.—Head Discharge Charts for Asbestos-Cement Pipes—Comparison of Experimental Results with Exponential Equation.

but it was found desirable, for reasons discussed later, to increase this to seven locations for a repeat test. Gauge locations are shown in Figs. 2 and 3. The distance between the gauges was obtained by chaining and the static level of the gauges by survey traverse.

Pressure heads during the tests were measured using "Lawrence" 12-in. Bourdon Tube gauges. These gauges were calibrated before and after the tests against a "Barnet" dead-load gauge tester. During the tests the gauges were regularly checked for change in calibration by comparing them with a standard gauge tester. No significant changes in calibration were observed.

The 15-in. line was tested at flow rates between 422 g.p.m. and 1,411 g.p.m. The corresponding total head drops over the 16,455 ft. test section were 4.25 ft. and 36.50 ft., respectively. The error in measuring head loss is estimated at 0.7 ft.

Two series of tests were run on the 21-in. line; the first in November, 1967, and the second in February, 1968. In the first series the flow was varied between 1,250 and 2,950 g.p.m. Computations of friction gradient given in this report are based on a test length of 16,394 ft. The variation in total head over this length varied from 5.88 ft. to 27.12 ft. The error in measuring head loss is estimated at 0.6 ft. For the second test series the test length was increased to 19,618 ft. and friction gradients were measured over a flow range from 1,210 g.p.m. to 2,950 g.p.m. The corresponding total head drops were 5.8 and 33.0 ft., respectively. The error in the measurement of head loss is estimated at 0.8 ft.

In the reduction of the test results no allowance has been made for minor losses at air valves, scour valves junction or fully-opened stop valves. The maximum error introduced by the neglect of these losses is less than 1%.

The accuracy of the experimental results at the highest flow rates is estimated at approximately 3%. Experimental errors increase in inverse proportion to the gradient as the flow rate and measured head differences between gauges become less. Consequently, in assessing the results greater weight is given to the results at the higher flow rates.

Test Results, 21-in. Line:

TEST SERIES 1—NOVEMBER, 1967.—Friction gradients over the 16,394 ft. test section between gauges A and C (Fig. 2) are plotted on Fig. 4. Within experimental accuracy the gradients between gauges A and B (13,257 ft.) and B and C (3,137 ft.) agreed. However, the gradient between gauges C and D (7,418 ft.) was some 25% higher. The reason for this was not known and it was decided to repeat the test run to try to isolate further the region of high head loss. Consequently further gauges were located upstream, in the middle and downstream of the S-bend section in the pipeline (Gauges X, Y and Z, Fig. 3) and the tests repeated.

TEST SERIES 2—FEBRUARY, 1968.—The measured gradients over the 19,618 ft. test section between gauges A and Y are shown in Fig. 4 and agree closely with the earlier test results. Within experimental error the friction gradients between the intermediate gauges A, B, C and Y were also consistent with the mean value whilst the three gauges in the vicinity of the S-bend gave results in close agreement with each other. Over section Z-D (3,694 ft.) the friction gradient was some 40% above the mean value and corresponds to an additional loss above friction of approximately 1.5 ft. The exact reason for this cannot be ascertained but, as it is in a relatively straight section of the pipeline, it can only be the result of a partial blockage from air or some other obstruction. For this reason gradients over section Z-D have been excluded from the results.

COMPARISON WITH EXPONENTIAL EQUATION.—In Fig. 4 the experimental results are compared with the exponential relationship (Eq. 3) based on an assumed pipe diameter of 19.92 in. This diameter corresponds to that stated by the manufacturers and is based on measurements from a large number of pipes. As an asbestos-cement pipe is formed against a steel mandril of constant diameter, close tolerance in diameter is maintained. A check of the diameters of 40 pipes taken at random from stock showed a standard deviation in diameter of less than 0.2% of the assumed value.

The experimental results are approximately 5% higher than those given by the exponential relationship which consequently can be taken as a close estimate of the friction loss of new pipe installed under field conditions.

Test Results, 15-in. Line:

Test results for the 15-in. line reduced to a standard temperature of 60°F. (Vallentine, Ref. 2) are shown in Fig. 4 on which the exponential equation of Vallentine (Eq. 3) is also plotted.

The pipe diameter of 14.30 in. stated on Fig. 4 corresponds to that given by the manufacturer from measurements on this class of pipe. A check of the diameter of 40 pipes selected at random from stock showed a standard deviation in diameter of less than 0.2% of this value.

Within experimental accuracy friction gradients between individual gauges corresponded with the mean over the entire test section.

The experimental points are approximately 8% higher than those given by the exponential equation as compared to 5% higher as obtained from the tests on the new 21-in. dia. pipeline. This may indicate a small increase in roughness due to ageing but as the difference is of the same order as the experimental accuracy, no firm conclusion can be drawn. The results do indicate, however, that any effect of ageing over the 7 years that the 15-in. line has been in service is relatively small.

DISCUSSION AND CONCLUSIONS

The field and laboratory tests on asbestos-cement pipes, ranging in size from $2\frac{1}{4}$ in. to 21 in. dia., show that friction loss can be approximated within normal engineering accuracy by the exponential equation proposed by Vallentine (Ref. 2) from laboratory tests on 4-in. asbestos-cement pipelines (Eq. 3). This is the equation which has been used in the preparation of the flow resistance chart recommended for use in the design of asbestos-cement pipelines by the manufacturers, James Hardie and Coy. Pty. Limited.

The test results on the 15-in. and 21-in. dia. pipelines installed under field conditions do indicate, however, friction gradients which are slightly higher than those given by the exponential relationship. This increase is of the order of 5 to 10% and should be allowed for in the design of large pipelines. The reasons for the increase could be the result of non-similarity effects between the laboratory and field tests and/or small additional losses at the joints as a result of deflections in the pipes during construction and/or pipe ageing. It is clear from the results, however, together with the results of laboratory tests on straight pipes at various joint spacings, that the effect of each of these factors on the pipe roughness is small.

Test results on the 15-in. pipeline showed that for asbestos-cement pipelines carrying chlorinated water the increase in pipe roughness over a period of 7 years was small.

ACKNOWLEDGMENTS

The author wishes to acknowledge the assistance given by James Hardie and Coy. Pty. Limited in undertaking this study. In particular, the author thanks Mr. B. Dunn and Mr. P. Knight of James Hardie and Coy. Pty. Limited and Mr. H. A. Leonard, Consulting Engineer to Warwick City Council, for their assistance in arranging and undertaking the field tests.

Thanks are also given to the staff of the Water Research Laboratory of the University of New South Wales for their helpful discussions and suggestions.

References

1. ACKERS, P.—Charts for the Hydraulic Design of Channels and Pipes. 2nd ed. *Gt. Britain. D.S.I.R. Hydraulics Research Station, Hydraulics Research Paper No.* 2, 1963. London, H.M.S.O., 1963, 49 p.
2. VALLENTINE, H. R.—Chart for Flow Resistance of Asbestos-Cement Pipes. *Australian Civ. Engg. and Construction,* Vol. 1, No. 5, Feb., 1960, pp. 38-42.