IS 12709 (1994): glass-fibre reinforced plastic (GRP) pipes joints and fittings for use for potable water supply [CED 50: Plastic Piping System]

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IS 12709 : 1994
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भारतीय मानक

पेय जल पूर्ति के लिए प्रयुक्त कांच रेशे से प्रबलित प्लास्टिक पाईप, जोड़ और फिटिंग — विशिष्टि

(पहला **पुनरीक्षण**)

Indian Standard

GLASS FIBRE REINFORCED PLASTICS (GRP) PIPES, JOINTS AND FITTINGS FOR USE FOR POTABLE WATER SUPPLY — SPECIFICATION

(First Revision)

UDC 621·643·2 : 678·5/·8·067·5 : 628·1/·2

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

May 1994

Price Group 9

AMENDMENT NO. 1 OCTOBER 1995
TO
IS 12709 : 1994 GLASS FIBRE REINFORCED PLASTICS (GRP) PIPES, JOINTS AND FITTINGS FOR USE FOR POTABLE WATER SUPPLY — SPECIFICATION

(First Revision)

(*Page* 3, *Table* 2) — Add the following at the end:

Nominal Diameter, DN	Outside Diameter, OD	Tolerance	
2 200	2 248	+7.0	
2 400	2 452	+7.5	
2 600	2 656	+8.0	−2.0
2 800	2 860	+8.5	
3 000	3 064	+9.0	

(*Page* 11, *Annex* E, *clause* E-6.1) — Substitute the following for the existing:

"**E-6.1** For each test piece, calculate the apparent hoop tensile strength at failure σ gi (in kN/m) from the following equation:

$$\sigma gi = \frac{F}{2\,W\,\mathrm{Sin}^2\theta}$$

where

F = failure load, kN;

W = width of test piece, m; and

θ = plane angle between hoop oriented reinforcement and longitudinal axis of the pipe (helix angle).

(CED 50)

Reprography Unit, BIS, New Delhi, India

AMENDMENT NO. 2 NOVEMBER 1996
TO
IS 12709 : 1994 GLASS FIBRE REINFORCED PLASTICS (GRP) PIPES, JOINTS AND FITTINGS FOR USE FOR POTABLE WATER SUPPLY — SPECIFICATION

(First Revision)

(*Page* 1, *clause* **1.2**) — Substitute the following for the existing:

'**1.2** Provisions relating to fittings fabricated from GRP pipes or by moulding process and joints covered in this standard are for guidance only.'

(*Page* 2, *Table* 1) — For '*Max* Inside Diameter Range, ID' put '}' against the entries 714, 816 and 918.

(*Page* 3, *clause* **7.2**, *line* 1) — Substitute 'effective' *for* 'nominal'.

(*Page* 3, *clause* **7.2.1**, *line* 1) — Substitute 'effective' *for* 'nominal'.

(*Page* 3, *clause* 9) — Substitute the following for the existing:

'**9 WORKMANSHIP**

Workmanship shall be in accordance with good practices as listed in Table 10 and shall meet the acceptance criteria specified.

Table 10 Allowable Defects

Name	Definition	Visual Acceptance Levels
Chip	A small piece broken off an edge or surface	Maximum dimension of break 6.5 mm
Crack	An actual separation of the laminate, visible on opposite surfaces, and extending through the thickness	None
Crack, surface	Crack existing only on the surface of the laminate	Maximum length, 6.5 mm
Crazing	Fine cracks at or under the surface of a laminate	Maximum dimension of crazing, 2.5 mm
Delamination, edge	Separation of the layers of material at the edge of a laminate	Maximum dimension, 6.5 mm
Delamination internal	Separation of the layers of material in a laminate	None
Dry-spot	Area of incomplete surface film where the reinforcement has not been wetted with resin	Maximum diameter, 14 mm
Foreign inclusion (metallic)	Metallic particles included in a laminate which are foreign to its composition	Maximum dimension, 1.5 mm
Foreign inclusion (non-metallic)	Non-mettallic particles of substance included in a laminate which seem foreign to its composition	Maximum dimension, 1.5 mm
Fracture	Rupture of laminate surface without complete penetration	Maximum dimension, 29 mm
Air bubble (void)	Air entrapment within and between the plies of reinforcement, usually spherical in shape	Maximum diameter, 3.0 mm
Blister	Rounded elevation of the surface of a laminate, with boundaries that may be more or less sharply defined, somewhat resembling in shape a blister on the human skin	Maximum diameter, 6.5 mm; height from surface not to be outside drawing tolerance

Price Group 1

AMENDMENT NO. 3 APRIL 2004
TO
IS 12709 : 1994 GLASS FIBRE REINFORCED PLASTICS (GRP) PIPES, JOINTS AND FITTINGS FOR USE FOR POTABLE WATER SUPPLY — SPECIFICATION

(First Revision)

(*Page* 1, *clause* **4.1.2**, *line* 3) — Substitute '248' *for* '240'.

(CED 50)

Reprography Unit, BIS, New Delhi, India

AMENDMENT NO. 4 JUNE 2011
TO
IS 12709 : 1994 GLASS FIBRE REINFORCED PLASTICS (GRP) PIPES, JOINTS AND FITTINGS FOR USE FOR POTABLE WATER SUPPLY — SPECIFICATION

(First Revision)

(*Page* 2, *Table* 1) — Insert the following at appropriate places in ascending order in the table:

Nominal Diameter, DN	Inside Diameter Range, ID		Tolerances on Declared ID
	Min	*Max*	
1 300	1 295	1 320	±5
1 500	1 495	1 520	±5

[*Page* 3, *Table* 2 (*see also Amendment No.* 1)] — Insert the following at appropriate places in ascending order in the table:

Nominal Diameter, DN	Outside Diameter, OD	Tolerance
1 300	1 330	±5
1 500	1 534	±5

(*Page* 6, *Table* 5) — Insert the following at appropriate places in ascending order in the table:

Nominal Diameter	Beam Load	Minimum Longitudinal Tensile Strength in kN/m of Circumference, for Pressure Class				
DN	P	PN 3	PN 6	PN 9	PN 12	PN 15
1 300	—	152	226	345	393	468
1 500	—	175	265	397	454	540

(*Page* 6, *Table* 6) — Insert the following at appropriate places in ascending order in the table:

Nominal Diameter	Minimum Hoop Tensile Strength of Pipe Wall in kN/m Width of Circumference for Pressure Class				
mm	PN 3	PN 6	PN 9	PN 12	PN 15
1 300	790	1 580	2 369	3 159	3 949
1 500	911	1 823	2 734	3 645	4 556

(*Page* 11, *clause* **E-5.3**) — Substitute the following for the existing:

‘Load the test piece by separating the mounts at a rate not exceeding 2.5 mm/min and record the maximum force resisted by the test piece.’

(CED 50)

Reprography Unit, BIS, New Delhi, In

Plastic Pipes and Fittings Sectional Committee, CED 50

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Plastic Pipes and Fittings Sectional Committee had been approved by the Civil Engineering Division Council.

Fibre glass reinforced plastic (GRP) pipes is a matrix of composite of glass fibre, thermosetting polyester resin and fillers. The pipes so manufactured are light in weight and have smooth interior surface.

This standard has been prepared with a view to providing guidance for the manufacturing, the selection and purchase of glass fibre reinforced thermosetting resin pipes for use as pressure pipes in a potable water supply for both above and underground installations.

This standard was first published in 1989. In this first revision the committee, in view of the experience gained, effected the following major modifications:

i) Pipes meant for potable water applications only have been covered.

ii) Irrespective of the method of manufacture, pipes continue to be designated by the nominal diameter. However depending upon the method of manufacture two series, namely one based on inside diameter and the other based on outside diameters have been covered in this specification.

iii) Provisions for fittings meant to be used with these pipes have been included.

iv) System of jointing of GRP pipes has been elaborated permitting various methods of jointing.

v) For establishing the suitability of pipes for potable water, necessary tests for the same have been included.

Pipes of higher sizes, pressure ratings and stiffness classes would be covered subsequently provided demand of such pipes is there and necessary data are generated for their inclusion.

In the preparation of this standard, assistance was derived from the following:

a) ISO 7370-1983	Glass fibre reinforced thermosetting plastics (GRP) pipes and fittings — Nominal diameters, specified diameters and standard lengths, published by International Organisation for Standardization
b) ASTM D 2992-1987	Standard practice for obtaining hydrostatic or pressure design basis for "Fibreglass" (Glass-fibre-reinforced thermosetting-resin) pipes and fittings published by American Society for Testing and Materials
c) ASTM D 3517-1986	Specification for fibreglass (Glass-fibre-reinforced thermosetting resin) pressure pipe, published by American Society for Testing and Materials
d) ANSI/AWWA C 950-1981	Glass-fibre-reinforced thermosetting-resin pressure pipe, published by American Water Works Association
e) BS 5480-1990	Specification for glass fibre resin forced plastic (GRP) pipes, joints and fittings for use for water supply and sewerage, issued by British Standards Institution

The composition of the Technical Committee responsible for the formulation of this standard is given at Annex H.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value shall be the same as that of the specified value in this standard.

Indian Standard

GLASS FIBRE REINFORCED PLASTICS (GRP) PIPES, JOINTS AND FITTINGS FOR USE FOR POTABLE WATER SUPPLY — SPECIFICATION

(First Revision)

1 SCOPE

1.1 This specification covers requirements for materials, dimensions, classification, testing and type of joints of machine-made pipes with glass fibre reinforced thermosetting resin with or without aggregate filler having nominal diameter from 200 mm to 3 000 mm for use at pressure up to 1 500 kPa for conveyance of potable water.

1.2 Provisions relating to fittings fabricated from GRP pipes or by moulding process have also been covered.

2 REFERENCES

2.1 The folllowing Indian Standards are necessary adjuncts to this standard:

IS No.	*Title*
5382 : 1985	Rubber sealing rings for gas mains, water mains and sewers (*first revision*)
6746 : 1994	Unsaturated polyester resin systems for low pressure fibre reinforced plastic
9845 : 1986	Method of analysis for the determination of and/or overall migration of constituents of plastic materials and articles intended to come into contact with foodstuffs
11273 : 1992	Woven roving fabrics of 'E' glass fibre
11320 : 1985	Glass fibre rovings for the reinforcement of polyester and epoxide resin systems (*first revision*)
11551 : 1986	Glass fibre chopped strand mat for the reinforcement of polyester resin system

3 TERMINOLOGY

3.1 Glass Fibre Pipe

A tubular product containing glass fibre reinforcements embedded in or surrounded by cured thermosetting resin. The composite structure may contain aggregate (silicious), fillers, thixotroic agents. Thermoplastic or thermosetting liner and/or surface layer may be included.

3.2 Surface Layer

A resin layer, with or without filler, or reinforcements, or both, applied to the exterior surface of the pipe structural wall.

3.3 Liner

A resin layer, with or without filler, or reinforcement, or both, forming the interior surface of the pipe.

3.4 Tests

3.4.1 *Type Test*

Tests carried out whenever a significant change is made in the design, composition or process of manufacturing and/or at a specified frequency in order to establish the suitability and performance capability of the pipes.

3.4.2 *Acceptance Test*

Tests carried out on samples taken from a lot for the purpose of acceptance of the lot.

4 CLASSIFICATION

4.1 The pipes have been classified on the basis of pressure rating and stiffness class as given in **4.1.1** and **4.1.2**.

4.1.1 *Pressure Classes (PN)*

Five pressure classes of pipes namely, PN 3, PN 6, PN 9, PN 12 and PN 15 correspond to the working pressure ratings of 300, 600, 900, 1 200 and 1 500 kPa respectively.

NOTES

1 The working pressure ratings mentioned above may have to be changed for use at fluid temperature greater than 43.5°C, in accordance witht the manufacturer's recommendations.

2 The above pressure classes correspond to the long term hydrostatic design pressure categories (*see* **15**).

4.1.2 *Stiffness Classes (SN)*

Four stiffness classes of pipes namely A, B, C and D correspond to minimum pipe stiffness values of 62, 124, 240 and 496 kPa respectively at 5% deflection.

5 SIZE DESIGNATION AND NOMINAL DIAMETER

Size designation of the pipe is based on the nominal diameter, DN. Nominal diameter shall be chosen from those given below:

200, 250, 300, 350, 400, 450, 500, 600, 700, 800, 900, 1 000, 1 100, 1 200, 1 400, 1 600, 1 800, 2 000, 2 200, 2 400, 2 600, 2 800 and 3 000 mm.

6 MATERIALS

6.1 Resins

Appropriate type of unsaturated polyester resin systems conforming to IS 6746 : 1994 shall be used.

6.1.1 The resin and additives used shall be such that they contain no ingredients, that is, in an amount that has been demonstrated to migrate into water in quantities that are considered to be toxic; satisfying the potability of water as determined by tests specified in **16**.

6.2 Glass Fibre Reinforcement

Glass fibre reinforcement shall be of commercial grade E type and shall conform to IS 11273 : 1992, IS 11320 : 1985 or IS 11551 : 1986, as appropriate.

6.3 Other Materials

6.3.1 *Aggregates*

Siliceous sand of a size range between 0.05 mm and 0.8 mm may be incorporated in the composite structure.

6.3.2 *Filler*

Inert fillers (with particle size below 0.05 mm) may be incorporated either on their own or with aggregates.

6.3.3 *Additives*

Additives may be incorporated for modifying the properties of the resin.

7 DIMENSIONS

7.1 Specified Diameter of Pipes

7.1.1 Inside diameters of pipes for each of the size designation shall be as specified in the manufacturer's data sheet, current at the time of purchase. The inside diameter so specified shall be within the range given in Table 1 and shall meet the tolerances, as specified.

7.1.1.1 The inside diameter shall be measured in accordance with **A-1.1**.

7.1.2 Alternatively, the outside diameter of pipes for each of the size designation shall be as given in Table 2; subject to the tolerances, as specified.

7.1.2.1 The outside diameter shall be measured in accordance with **A-1.2**.

Table 1 Specified Inside Diameters and Tolerances

(*Clauses* 7.1.1 *and* 7.4)

All dimensions in millimetres.

Nominal Diameter, DN	Inside Diameter Range, ID		Tolerances on Declared ID
	Min	*Max*	
200	196	204	± 1.5
250	246	255	± 1.5
300	296	306	± 1.8
350	346	356	± 2.0
400	396	408	± 2.4
450	446	459	± 2.7
500	496	510	± 3.0
600	596	612	± 3.6
700	695	714	± 4.2
800	795	816	
900	895	918	
1 000	995	1 020	± 5.0
1 100	1 095	1 120	
1 200	1 195	1 220	
1 400	1 395	1 420	
1 600	1 595	1 620	
1 800	1 795	1 820	
2 000	1 995	2 020	
2 200	2 195	2 220	± 6.0
2 400	2 395	2 420	
2 600	2 595	2 620	
2 800	2 795	2 820	
3 000	2 995	3 020	

Table 2 Specified Outside Diameters and Tolerances

(*Clauses* 7.1.2 *and* 7.4)

All dimensions in millimetres.

Nominal Diameter, DN	Outside Diameter, OD	Tolerance	
200	208	+ 2.0	
250	259	+ 2.1	
300	310	+ 2.3	
350	361	+ 2.4	
400	412	+ 2.5	
450	463	+ 2.7	
500	514	+ 2.8	
600	614	+ 3.0	
700	718	+ 3.3	− 2.0
800	820	+ 3.5	
900	922	+ 3.8	
1 000	1 024	+ 4.0	
1 100	1 126	+ 4.3	
1 200	1 228	+ 4.5	
1 400	1 432	+ 5.0	
1 600	1 636	+ 5.5	
1 800	1 840	+ 6.0	
2 000	2 044	+ 6.5	

7.2 Lengths

Pipes shall be supplied in nominal lengths of 6 m, 9 m and 12 m. A maximum of 10 percent of the pipe section may be supplied in random lengths. The length of the pipe shall be measured in accordance with **A-2.1**.

NOTE – Lengths other than those specified above may be supplied as agreed between the purchaser and the manufacturer.

7.2.1 The tolerance on nominal lengths shall be within ± 25 mm.

7.3 Out of Squareness of Pipe

All points around each end of a pipe unit shall fall within ±6.5 mm or ±0.5 percent of the nominal diameter of the pipe whichever is greater, to a plane perpendicular to the longitudinal axis of the pipe when measured in accordance with **A-3.1**.

7.4 Wall Thickness

The minimum wall thickness at any point shall not be less than the wall thickness specified in the manufacturer's data sheets current at the time of purchase. The manufacturer shall ensure that the wall thickness specified in his data sheet shall be such as to satisfy the inside or outside diameters specified in Table 1 or Table 2 as the case may be and the tests specified in this standard.

7.4.1 Wall thickness shall be measured to an accuracy of 0.1 mm in accordance with **A-4.1**.

8 JOINTS

The pipe shall have a joining system that shall provide for fluid tightness for the intended service condition.

8.1 Unrestrained

Pipe joints capable of withstanding internal pressure but not longitudinal forces.

8.1.1 *Coupling or Socket and Spigot Gasket Joints*

Provided with groove(s) either on the spigot or in the socket to retain an elastomeric gasket(s) that shall be the sole element of the joint to provide watertightness. For typical joint detail (*see* Fig. 1).

8.1.2 *Mechanical Couplings*

8.2 Restrained

Pipe joints capable of withstanding internal pressure and longitudinal forces.

8.2.1 Joints similar to those in **8.1.1** with supplemental restraining elements.

8.2.2 *Butt Joint* — with laminated overlay

8.2.3 *Socket-and-Spigot* — with laminated overlay.

8.2.4 *Soocket-and-Spigot* — adhesive bonded.

8.2.5 *Flanged*

8.2.6 *Mechanical*

8.3 Gaskets

Elastomeric gaskets when used with this pipe shall conform to the requirements of IS 5382 : 1985.

9 WORKMANSHIP

9.1 Pipes shall be free from all defects including indentations, delamination, bubbles, pinholes, cracks, pits, blisters, foreign inclusions and resin-starved areas that due to their nature, degree, or extent detrimentally affect the strength and serviceability of the pipe. The pipe shall be as uniform as commercially practicable in colour opacity, density and other physical properties.

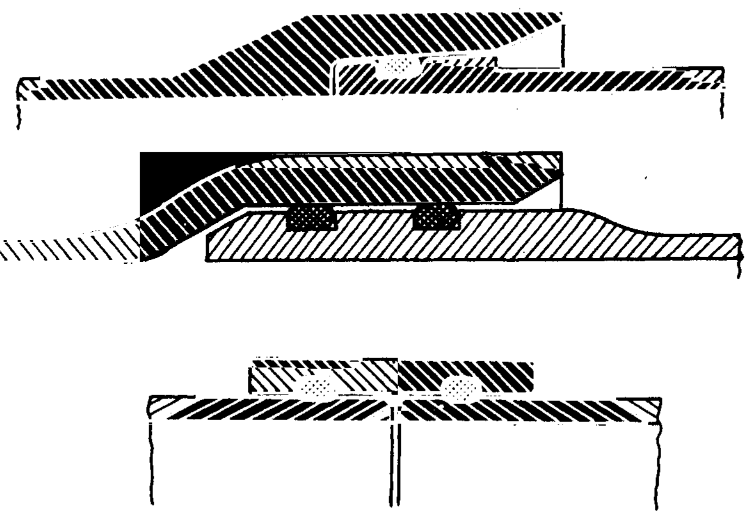


FIG. 1 TYPICAL JOINTS

9.2 The inside surface of each pipe shall be free of bulges, dents, ridges and other defects that result in a variation of inside diameter of more than 3.2 mm from that obtained on adjacent unaffected portions of the surface. No glass fibre reinforcement shall penetrate the interior surface of the pipe wall.

9.3 Joint sealing surfaces shall be free of dents, gouges, and other surface irregularities that will affect the integrity of the joints.

10 PIPE STIFFNESS

10.1 Each length of pipe shall have sufficient strength to exhibit the minimum pipe stiffness (F/Δ_Y) specified in Table 3 when tested in accordance with Annex B

Table 3 Pipe Stiffness at 5 Percent Deflection

Stiffness Class (SN)	Minimum Stiffness of Pipe of DN, at 5 Percent Deflection, kPa		
	200 mm	250 mm	300 mm and above
A	-	-	62
B	-	124	124
C	248	248	248
D	496	496	496

where

F = load per unit length in kN per metre length, and

Δ_Y = vertical pipe deflection, in metres.

10.1.1 Pipes shall be capable of being deflected to level 'X' with no visible damage in the test specimen evidenced by surface cracks and to level 'Y' with no indication of structural damage as evidenced by interlaminar separation, separation of the liner or surface layer (if incorporated) from structural wall, tensile failure of the glass fibre reinforcement and fracture or buckling of the pipe wall, when tested in accordance with Annex B.

Deflection Level	*Ring Deflection Without Damage or Structural Failure, in Percent for pipe of Stiffness Class*			
	A	B	C	D
Level, X	18	15	12	9
Level, Y	30	25	20	15

NOTE – This is a visual observation (made with the unaided eye) for quality control purposes only and should not be considered a simulated service test. In actual use this product is not recommended for deflections above 5%. Since the pipe stiffness values (F/Δ_Y) shown in Table 3 vary, the percent deflection of the pipe under given set of installation conditions will not be constant for all pipes. To avoid possible misapplication, care should be taken to analyse all conditions which might affect performance of the installed pipe.

11 FITTINGS

11.1 General

All GRP fittings, such as bends, tees, junctions and reducers, shall be equal or superior in performance to pipe of the same classification and shall be smoothly finished internally.

GRP fittings are not subject to tests for strength and it is essential that external restraint be considered for installation.

11.2 Fittings Made from Straight Pipe

The fitting shall be fabricated from complete pipes or portions of straight pipe complying with this standard as applicable for the pipe classification. The fitting shall comply with the declared design requirements and be suitably mitred. The mitre shall be overwrapped externally and, if practicable, internally with woven roving and/or chopped strand mat to ensure the longitudinal and circumferential tensile strength is at least equal by design to that of the pipe with which the fitting is to be used.

11.3 Fittings Made by Moulding

Moulded GRP fittings shall be made by hand lay-up, contact moulding, hot or cold press moulding or tape winding.

11.4 Tolerances for GRP Fittings

11.4.1 Except for flanged pipework, which may require closer tolerances, the permissible deviations from the stated value of the angle of change of direction of a fitting such as a bend, tee or junction shall not exceed ± 1°.

11.4.2 Except for flanged pipework, which may require closer tolerances, the permissible deviations on the manufacturer's declared length of a fitting, exclusive of the socket where applicable, shall be ± 25 mm taken from the point of intersection to the end of the fitting.

12 HYDRAULIC TEST

12.1 General

12.1.1 Working pressure P_W in the system shall not exceed the pressure class of the pipe, that is, $P_W \leq P_N$.

12.1.2 When surge pressure is considered the maximum pressure in the system due to working pressure plus surge pressure, the same shall not exceed 1.4 times the pressure class of pipe:

$$P_W + P_N \not> 1.4\ \text{PN}$$

NOTE – Special design considerations shall be given to sustained pressure surge.

12.2 Soundness

Each length of pipe of nominal diameter up to 1 400 mm shall withstand without leakage or cracking the internal hydrostatic test pressures as specified in Table 4 for the applicable class when tested in accordance with Annex C. For pipes of nominal diameter above 1400 mm, the frequency of hydrostatic leak tests shall be as agreed between the manufacturer and the purchaser.

Table 4 Hydrostatic Test Pressures

Pressure Class PN	Hydrostatic Test Pressure kPa
3	600
6	1 200
9	1 600
12	2 400
15	3 000

13 LONGITUDINAL STRENGTH

For sizes up to DN 600 the pipe shall withstand, without failure, the beam loads specified in Table 5, when tested in accordance with **D-1**. For pipe sizes larger than DN 600 and alternatively for smaller sizes adequate beam strength shall be demonstrated by tensile tests conducted in accordance with **D-2** for pipe wall specimens oriented in the longitudinal direction. The minimum tensile strength specified in Table 5 shall be complied with.

NOTE – The values listed in Table 5 are the minimum criteria for pipes made to this standard. The values may not be indicative of the axial strength or of the axial strength required by some installation conditions and joint configurations.

14 HOOP TENSILE STRENGTH

All pipes manufactured as per this specification shall meet or exceed the hoop tensile strength shown for each size and class in Table 6, when tested in accordance with Annex E.

15 LONG TERM HYYDROSTATIC DESIGN PRESSURE TEST

The pressure classes given in **4.1.1** shall be based on long term hydrostatic design pressure data obtained in accordance with Annex F and categorized in accordance with Table 7. Pressure classes are based on extrapolated strength at 50 years.

16 TESTS TO ESTABLISH POTABILITY OF WATER

16.1 Pipe specimen shall be subjected to tests specified below in order to establish the suitability of these pipes for use in carrying potable water:

i) Smell of the extract,
ii) Clarity of the colour of the extract,
iii) Acidity and alkality,
iv) Global migration,
v) UV absorbing material,
vi) Heavy metals,
vii) Unreacted monomers (styrens), and
viii) Biological tests.

16.1.1 Method of preparing extracts for carrying out the tests mentioned in **16.1** is as given below:

Extracts shall be prepared for the chemical tests and biological tests by dipping in separate beakers pieces of GRP pipes (5 cm x 5 cm) such that surface in contact with the extractants, prepared as mentioned in **16.1.1.1** and **16.1.1.2**, 1 cm²/2 ml. The beakers with the sample and the extractants shall be kept at 60 ± 1°C for 2 hours and at 40 ± 1°C for 24 hours respectively for chemical and biological tests. The extracts thus prepared shall be transferred in transparent bottles for carrying out the specified tests. Blanks (extractants only) shall also be kept in parallel under identical manner, as controls.

Table 5 Beam Strength Test Loads and Longitudinal Tensile Strength of Pipe Wall

(*Clause* 13)

Nominal Diameter	Beam Load P	Minimum Longitudinal Tensile Strength in kN/m of Circumference for Pressure Class of				
DN	kN	PN 3	PN 6	PN 9	PN 12	PN 15
200	3.6	102	102	102	102	102
250	5.3	102	102	102	102	110
300	7.1	102	102	102	112	136
350	9.8	102	102	115	131	154
400	13.3	102	102	130	149	177
450	17.8	102	102	138	159	185
500	19.6	102	102	154	176	205
600	28.5	102	123	184	211	246
700	-	102	140	215	246	280
800	-	102	154	231	265	304
900	-	105	174	260	298	341
1 000	-	122	193	290	331	379
1 100	-	127	212	318	363	417
1 200	-	140	212	318	363	431
1 400	-	164	247	371	423	504
1 600	-	185	283	423	484	574
1 800	-	206	318	476	545	646
2 000	-	231	329	492	563	678
2 200	-	254	361	541	619	745
2 400	-	280	394	591	676	813
2 600	-	301	427	640	732	880
2 800	-	326	459	690	789	949
3 000	-	347	492	739	844	1 016

Table 6 Minimum Hoop Tensile Strength of Pipe Wall

(*Clause* 14)

Nominal Diameter mm	Minimum Hoop Tensile Strength in kN/m Width of Circumference for Pressure Class				
	PN 3	PN 6	PN 9	PN 12	PN 15
200	122	244	366	488	610
250	152	304	456	608	760
300	182	364	546	728	910
350	213	426	639	852	1 065
400	243	486	729	972	1 215
450	273	546	819	1 092	1 365
500	304	608	912	1 216	1 520
600	365	730	1 095	1 460	1 825
700	425	850	1 275	1 700	2 125
800	486	972	1 458	1 944	2 430
900	547	1 094	1 641	2 188	2 735
1 000	608	1 216	1 824	2 432	3 040
1 100	668	1 336	2 004	2 672	3 340
1 200	729	1 458	2 187	2 916	3 645
1 400	851	1 702	2 553	3 404	4 255
1 600	972	1 944	2 916	3 888	4 860
1 800	1 094	2 188	3 282	4 376	5 470
2 000	1 215	2 430	3 645	4 860	6 075
2 200	1 337	2 674	4 011	5 348	6 685
2 400	1 458	2 916	4 374	5 832	7 290
2 600	1 580	3 160	4 740	6 320	7 900
2 800	1 701	3 402	5 103	6 804	8 505
3 000	1 823	3 646	5 469	7 292	9 115

16.1.1.1 Extractant for chemical tests specified in **16.2** to **16.8** shall be:

a) Double//triple glass distilled water,
b) 3% acetic acid (*m/v*) prepared in double/triple glass distilled water,
c) 8% ethanol (*v/v*) prepared in double/triple glass distilled water, and
d) 0.9% sodium chloride (*m/v*) prepared in double/triple glass distilled water.

16.1.1.2 Extractant for biological tests specified in **16.9** shall be:

a) Double/triple glass distilled water, and
b) 0.9% sodium chloride (*m/v*) prepared in double/triple glass distilled water.

Table 7 Long Term Hydrostatic Design Pressure Categories

(*Clause* 15)

Pressure Class PN	Minimum Calculated Values of Long Term Hydrostatic Design Pressure, kPa
3	540
6	1 080
9	1 620
12	2 160
15	2 700

16.2 Smell of the Extract

The extract when examined shall be free from odour.

16.3 Clarity of the Colour of the Extract

The extract shall be examined visually through test tube for the presence of any colour or turbidity. The extract shall be free from colouring materials and turbidity.

16.4 Acidity and Alkalinity

The extract shall be examined for the change of *p*H (using preferably digital-*p*H meter) due to migration of chemical additives. The *p*H of the extract shall be the same as that of corresponding blank (extractant without test piece).

16.5 Global Migration

100 ml of the extract shall be evaporated in a constant preweighted crucible. Total residue in 100 ml of the extract should not exceed 5 mg (*see also* IS 9845 : 1986).

16.6 UV Absorbing Materials

Extract shall be examined for the presence of UV absorbing materials by scanning the samples between 220 to 400 nm using double/triple glass distilled water as blank in spectrophotometer.

16.7 Heavy Metals

Extract shall be examined for the presence of heavy metals such as Pb, Cd, Mn, Cr, Cu, Co and Zn. Concentrations of Pb, Mn, Cr, Cu, Co and Zn should not exceed 1 ppm and concentrations of Cd should not exceed 0.1 ppm.

16.8 Unreacted Manomer (Styrene)

The total unreacted styrene concentrations of residual manomers in the extract should not exceed 0.2% by mass of the polymers.

16.9 Biological Tests

The extract shall be injected into ten healthy mice weighing 20 ± 2 g intravenously and intraperitoneally. Another ten healthy mice shall also be exposed to the corresponding blank (extractant without test piece) and at the end of four, eight, twelve and twentyfour hours, the mice shall be examined for the symptoms of toxicity. There should be no mortality or gross toxicity symptoms in the animals exposed to the extracts in comparison to those exposed to blank (extractant only).

17 SAMPLING, FREQUENCY AND CRITERIA FOR CONFORMITY

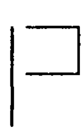
The sampling procedure to be adopted and the criteria for conformity shall be as given in Annex G.

18 MARKING

18.1 Both ends of pipe shall be marked with bold letters not less than 12 mm in height and in a colour and type that remains legible under normal handling and installation procedures. The markings shall include the following:

a) The manufacturer's name or trade-mark,
b) The nominal pipe diameter,
c) Class of pipe (pressure and stiffness), and
d) Batch No. or date of manufacture.

18.1.1 In addition the pipes shall be provided with the following mark on either ends:



18.2 BIS Certification Marking— Pipes may also be marked with the Standard Mark.

18.2.1 The use of the Standard Mark is governed by the provisions of Bureau of Indian Standards Act, 1986 and the Rules and Regulations made thereunder. The details of conditions under which the licence for the use of Standard Mark may be granted to manufacturers or producers may be obtained from the Bureau of Indian Standards.

ANNEX A

(*Clauses* 7.1.1.1, 7.1.2.1, 7.2, 7.3 *and* 7.4.1)

MEASUREMENT OF DIMENSIONS

A-1 MEASUREMENT OF DIAMETERS

A-1.1 Inside Diameter

Inside diameter shall be measured at 150 mm away from each end of the pipe section using a steel tape or an inside micrometer with graduation of 1 mm or less. Make two 90° opposing measurements at each point of measurement and average the readings.

A-1.2 Outside Diameter

A-1.2.1 Outside diameter shall be measured at 150 mm away from the joint seating surface at the outer edge of the pipe.

A-1.2.2 *Principle*

The circumference of the pipe is measured and by dividing by 3.142 (π) diameter is obtained.

A-1.2.3 Measurement shall be done by ordinary flexible tape or flexible tape suitably calibrated to read diameters directly. This tape shall comply with the following requirements:

a) it shall be made of stainless steel or some other suitable material.

b) it shall permit the reading to the nearest 1 mm.

c) it shall be graduated in such a way that neither its own thickness of the graduation has any influence on the result of the measurement, and

d) it shall have sufficient flexibility to conform exactly to the circumference of the pipe.

A-1.2.4 *Procedure*

Apply the tape on the whole of the circumference perpendicular to the axis of the pipe.

A-2 LENGTH

A-2.1 Length shall be measured with a steel tape having graduations of 1 mm or less. Lay the tape inside the pipe and measure the overall length of the pipe.

A-3 SQUARENESS OF PIPE END

A-3.1 Rotate the pipe on a mandrel or trunnions and measure the runout of the ends with a dial indicator. The total indicated reading is equal to twice the distance from a plane perpendicular to the longitudinal axis of the pipe. Alternatively when squareness of pipe ends is rigidly fixed by tooling, the tooling may be verified and reinspected at frequent intervals to ensure that the squareness of the pipe ends is maintained within the specified tolerances.

A-4 WALL THICKNESS

A-4.1 Measure with a micrometer caliper or other suitable thickness measuring device or instrument with graduation of 0.1 mm or less and take a series of four measurements equally spaced around the circumference of the pipe after removing the liner where provided. These measurements should be taken before end joint surface machining is done and some distance away from the pipe end. The average of all measurements shall meet or exceed the minimum value specified in manufacturer's data sheet.

ANNEX B

(*Clauses* 10.1 *and* 10.1.1)

TEST FOR PIPE STIFFNESS

B-1 PROCEDURE

B-1.1 Determine the pipe stiffness (F/Δ_Y) at 5 percent vertical deflection for the specimen using the apparatus and procedure described in **B-1.2, B-1.3** and **B-1.4.**

B-1.2 The apparatus shall consist of two parallel steel plates between which the test specimen is placed, and a means of uniform loading the pipe with a vertical load (*see* Fig. 2).

B-1.3 Load the specimen to 5 percent deflection with 2 minutes. Record the load.

B-1.4 Calculate the pipe stiffness using the formula given in **10.1.**

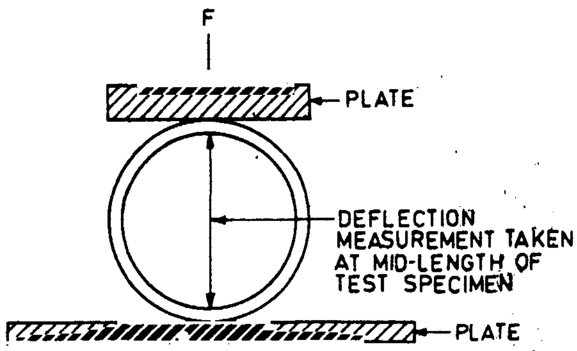


FIG. 2 SCHEMATIC DIAGRAM OF APPARATUS FOR DETERMINATION OF PIPE STIFFNESS

B-1.5 Load the specimen further to deflection level 'X' as per **10.1.1** and examine the specimen for visible damage evidenced by surface cracks. Then load the specimen to deflection level 'Y' as per **10.1.1** and examine for evidence of structural damage, as evidenced by interlaminar separation, separation of the liner or surface layer (if incorporated) from the structural wall, tensile failure of the glass fibre reinforcement and structure or bukling of the pipe wall.

ANNEX C

(*Clause* 12.2)

SOUNDNESS OF PIPE

C-1 PROCEDURE

Soundness shall be determined by a hydrostatic proof test. Place the pipe in a hydrostatic pressure testing machine that seals the ends and exerts no end loads. Fill the pipe with water expelling all air and apply internal water pressure at a uniform rate not to exceed 300 kPa/s until the hydrostatic test pressure specified in accordance with **12.2** (Table 4) is reached. Maintain this pressure for 1 minute. The pipe shall show no visual signs of weeping, leakage or fracture of the structural wall.

ANNEX D

(*Clause* 13)

LONGITUDINAL STRENGTH

D-1 BEAM STRENGTH

Place a 6 mm nominal length of pipe on saddles at end. Hold the ends of the pipe round during the test. Apply beam load for the diameter of pipe shown in Table 5 simultaneously to the pipe through two saddles located at the third points of the pipe (*see* Fig. 3). The loads shall be maintained for not less than 10 min with no evidence of failure. The testing apparatus shall be designed to minimize stress concentrations at the loading points.

D-2 LONGITUDINAL TENSILE STRENGTH

D-2.1 General

This method describes the test procedure to determine the longitudinal tensile strength of a reinforced plastics pipe by means of a tensile strength test carried out on strip cut from the pipe.

D-2.2 Apparatus

D-2.2.1 A tensile machine capable of indicating the force applied to the test piece with an accuracy of ± 1 percent of the indicated value.

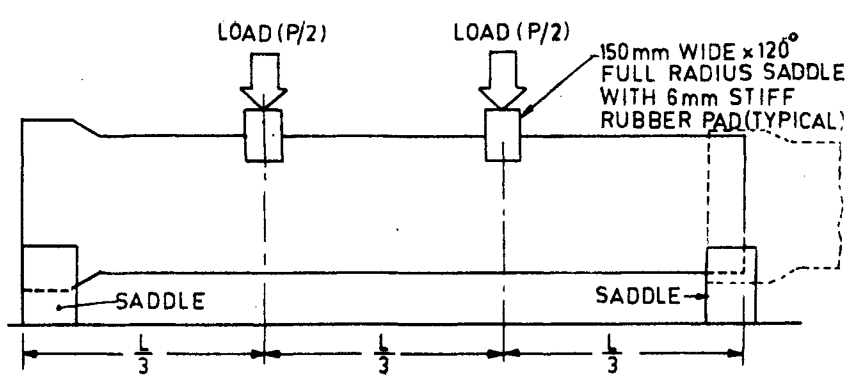


FIG. 3 BEAM STRENGTH — TEST SETUP

D-2.2.2 A means of measuring the width and thickness of the test piece to an accuracy of 0.1 mm.

D-2.3 Test Pieces

D-2.3.1 The test piece shall be strips cut from a pipe in the longitudinal direction and profiled to the dimensions shown in Fig. 4.

A minimum of three test pieces are required.

NOTE - If profile cutting is impractical, parallel-sided test pieces of width between $2e$ and $3e$ (*see* Fig. 4) shall be used, where e is the thickness of the test piece.

D-2.4 Test Conditions

Conduct the test at ambient temperature.

D-2.5 PROCEDURE

D-2.5.1 Measure the width w and thickness of the piece at the centre of the gauge length and at points within 5 mm of each end of the gauge length. Record the average width as w and the average thickness as e.

D-2.5.2 Grip the test piece in the testing machine with the test piece centreline along the loading axis of the machine.

D-2.5.3 Load the test piece by separating the grips at a rate to ensure failure occurs between 1 minute and 3 minutes. Record the maximum force as F.

D-2.5.4 Repeat **D-2.5.1** to **D-2.5.3** until three results have been obtained. Discard any test piece that breaks other than across the neck and test additional test pieces unitl three results are obtained.

D-2.6 Calculation

For each test piece, calculate the longitudinal tensile strength of the pipe per unit circumference T (in kN/m) using the following equation:

$$T = \frac{F}{w}$$

where

F is the failure force in N, and

w is the width of test piece in mm.

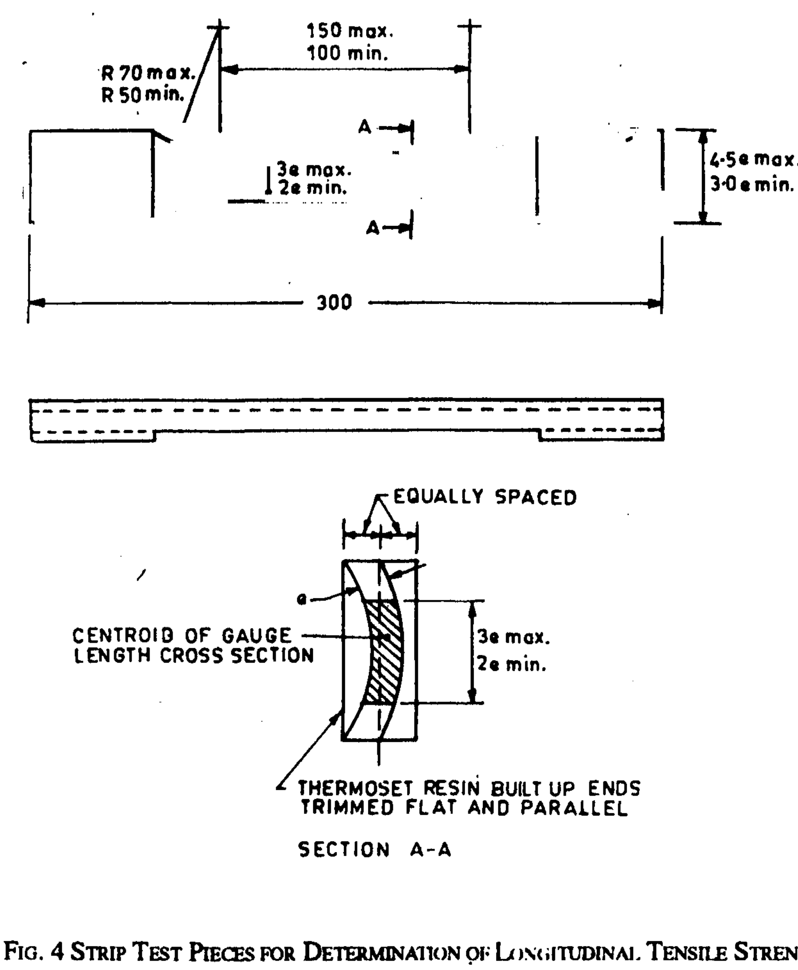


FIG. 4 STRIP TEST PIECES FOR DETERMINATION OF LONGITUDINAL TENSILE STRENGTH

ANNEX E

(*Clause* 14)

HOOP TENSILE STRENGTH

E-1 GENERAL

E-1.1 This method describes the test procedure to determine the hoop tensile strength of a reinforced plastics pipe by means of a split disc test.

E-2 APPARATUS

E-2.1 A testing machine capable of producing a progressive rate of separation of the split discs to produce failure of the test piece within 1 minute to 3 minutes of initial loading.

E-2.2 Rigid split discs similar to those shown in Fig. 5 that make even contact with the internal diameter of the test piece and that immediately prior to the test piece being loaded are not separated by more than 1 percent of the pipe diameter.

E-2.3 A force indicator capable of measuring the force applied with an accuracy of ± 3 percent.

E-2.4 A suitable means of measuring the width and thickness of the test piece with an accuracy of ± 0.1 mm.

E-3 TEST PIECES

E-3.1 The test piece (*see* Fig. 6) shall be a ring cut from a pipe. The minimum width of the test piece shall be 8 mm; the maximum width is dependent on the method of manufacture and the testing equipment available. The width of the test piece shall not exceed the width of the split disc. A minimum of three test pieces shall be taken to obtain a reliable average result.

E-4 TEST CONDITIONS

Conduct the test at ambient temperature.

E-5 PROCEDURE

E-5.1 Measure the width thickness of the test piece at diametrically opposed points.

E-5.2 Mount the test piece on the outside periphery of the split disc test fixture with the points of measurement at the split.

E-5.3 Load the test piece by separating the mounts at a rate not exceeding 2.5 mm/min ensuring failure to occur between 1 minute and 3 minutes and record the maximum force F resisted by the test piece and the time to failure.

E-6 CALCULATION

E-6.1 For each test piece, calculate the apparent hoop tensile strength at failure σ_{gi} (in kN/m) from the following equation :

$$\sigma_{gi} = \frac{F}{2w}$$

where

F = failure load (in N); and

w = width of the test piece (in mm).

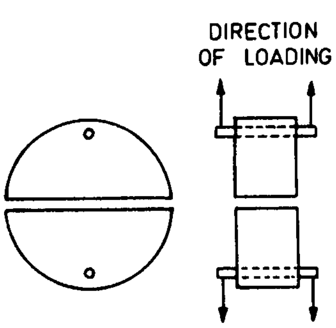


FIG. 5 SPLIT DISC

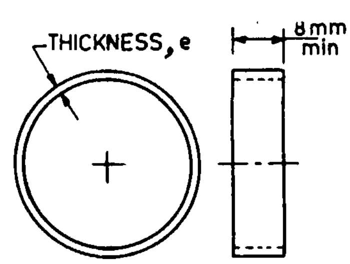


FIG. 6 SPLIT RING TEST PIECE

ANNEX F

(*Clause* 14)

LONG TERM HYDROSTATIC DESIGN PRESSURE TEST BY STRESS/STRAIN METHODS

F-1 GENERAL

F-1.1 This annex covers the procedure (static) for obtaining a hydrostatic design basis for fibre glass pipe by evaluating strength regression data derived from testing of pipes of similar material and construction for the purpose to establish its pressure rating.

For those products where no previous long term hydrostatic testing has been performed on similar products the full type testing as described in Method A shall be performed. When a hydrostatic design basis has already been established for a nominally similar pipe using the same manufacturing process, the manufacturer need only conduct the requalification test as described in Method B.

F-1.2 This practice can be used for the HDB determination for fibre glass pipe where the ratio of outside diameter to wall thickness is 10 : 1 or more.

F-1.3 Specimen end closures in the test methods may either be restrained or free depending on the application of the pipe.

F-1.3.1 *Restrained Ends*

Specimen are essentially stressed by internal pressure only in the hoop direction and the HDB is applicable for stress developed only in the hoop direction.

F-1.3.2 *Free Ends*

Specimen are stressed by internal pressure in both hoop and longitudinal directions such that the hoop streess is twice as large as the longitudinal stress. The procedure given in this standard are not applicable for evaluating stress induced by loading where the longitudinal stress exceeds 50% of the hydrostatic design stress.

F-2 DEFINITIONS

F-2.1 Failure

When the test specimen develops a leak, weeps or ruptures, it shall be considered to have failed except that leakage or failure within one diameter of the end closure shall not be considered as failure of the specimen.

F-2.2 Hoop Stress/Hoop Strain

The tensile stress/strain in the circumferential direction due to internal hydrostatic pressure.

F-2.2.1 The hoop stress shall be calculated by the following ISO equation:

$$\sigma h = P\,(D - tr)/2tr$$

where

σh = hoop stress in kPa,

D = average reinforced outside diameter in mm,

P = internal pressure in kPa, and

tr = minimum reinforced wall thickness in mm.

F-2.2.2 *Hoop Strain*

The hoop strain shall be calculated by substituting $EHT = \sigma h/\varepsilon$ in the ISO equation, given in **F-2.2.1**.

where

EHT = hoop tensile modulus of elasticity in kPa,

ε = hoop strain in cm/cm, and

σh = hoop stress in kPa.

F-2.2.2.1 Formula for hoop strain will thus be:

$$\varepsilon = \frac{P\,(D - tr)}{2\,tr} \times \frac{1}{EHT}$$

F-2.2.2.2 EHT shall be calculated from the equation:

$$EHT = \frac{E_1\,t_1 + E_2\,t_2 + \ldots.}{t_1 + t_2 + \ldots}$$

depending upon the layers of the composite

where E_1 and t_1 are the Young's modulus and the thickness of each of the layers of the composite and $t_1 + t_2 + \ldots\ldots$ is the thickness of the total composite.

F-2.3 Long Term Hydrostatic Strength (LTHS)

The estimated tensile stress/strain in the wall of the pipe in the circumferential orientation due to internal hydrostatic pressure that will cause failure of the pipe after 100 000 hours of pressure applied continuously.

F-2.4 Hydrostatic Design Basis (HDB)

Hoop stress/strain developed for fibre glass pipe by this practice and multiplied by a service design factor to obtain hydrostatic design stress or strain (HDS).

F-2.5 Hydrostatic Design Stress/Strain (HDS)

The estimated maximum tensile stress/strain in the wall of the pipe in the hoop orientation due to internal hydrostatic pressure that can be applied continuously with a high degree of certainty that failure of the pipe will not occur.

F-2.6 Pressure Rating (When Expressed with Reference to Pipe)

The estimated maximum pressure that the medium (water) in the pipe can exert continuously with a high degree of certainty that failure of the pipe will not occur.

F-2.7 Service Design Factor

A number equal to 1.00 or less that takes into consideration all the variables and degree of safety involved in GRP piping installation so that when it is multiplied by the HDB, an HDS and corresponding pressure rating is obtained. A safe and satisfactory piping installation results when good quality components are used and the installation is made properly.

The service design factor should be selected by the design engineer after evaluating fully the service conditions and engineering properties of the materials used in the manufacturing of pipe. A value of 0.555 is recommended in lieu of any specific information on typical water supply system.

F-2.8 Reinforced Wall Thickness

The thickness excluding the liner and the surface layer thickness.

F-3 SIGNIFICANCE AND USE

F-3.1 Procedure for estimating the long term hydrostatic stress/strain of fibre glass is essentially an extrapolation with respect to time of tests. Stress/strain at failure versus time plots are obtained.

F-3.2 The values obtained by this method are applicable only to conditions that duplicate these procedures. It is not likely that long term strength of pipe made by different processes or substantially different materials will be the same.

NOTE – It has been shown that the results obtained from this method tend to be conservative when compared to actual service use within the scope of the test method.

F-3.3 The hydrostatic design basis is in accordance with **F-5**.

F-3.4 Hydrostatic design stress/strain are obtained by multiplying hydrostatic design basis values by a service design factor, given in **F-2.7**.

F-3.5 Pressure rating for pipe of various dimensions may be calculated from the hydrostatic design stress/strain (HDS) value determined by testing one size of pipe, provided that the specific process and material are used both for test specimens and the pipe in question.

F-4 SUMMARY OF METHOD A

F-4.1 Procedure consists of exposing a minimum of 18 specimens of pipe to constant internal hydrostatic pressures at differing pressure levels in a controlled environment and measuring the time to failure for each pressure level.

F-4.1.1 The long term hydrostatic strength (stress/strain) of pipe is obtained by an extrapolation to 438 000 hours of a log-log linear regression line for hoop stress/strain versus time to failure, as described in **F-5** and HDB in accordance with **F-6**.

Time is treated as the dependent variable in the least square regression analysis.

F-5 LONG TERM HYDROSTATIC STRENGTH (LTHS)

F-5.1 The inside environment for the pipe test specimen shall be water. The outside environment shall be air. Other media may be used, but the environment shall be given in the test report. The test liquid shall be maintained within ± 3°C of the temperature.

F-5.2 Test at ambient temperatures between 10°C and 43.5°C and report the temperature range experienced during the tests.

NOTE – Tests indicate no significant effects on the long term hydrostatic pressure within the ambient temperature range specified.

F-5.3 Determine the average outside diameter and minimum reinforced wall thickness of each pipe test specimen in accordance with Annex A.

NOTE – If the test specimens contain an unreinforced liner, determine the wall thickness excluding the liner so that the thickness recorded is the reinforced wall thickness.

F-5.4 Measurement

Strain: A minimum of three strain gauges shall be mounted at the pipe test specimen's mid length, oriented in the circumferential direction, each gauge shall have a minimum effective measurement length of 6.35 mm. The reported hoop strain shall be the average of the three measured values.

Stress: The stress or pressure values for test shall be selected to obtain the requisite failure points.

F-5.5 The stress/strain shall be selected to obtain failure points as follows:

Hours		*Failure Points*
10 to 1 000		At least 4
1 001 to 6 000		At least 3
After 6 000		At least 3
After 10 000		At least 1
	Total	At least 18

F-5.5.1 Maintain the internal test pressure in each specimen corresponding to the selected stress/strain, within ± 35 kPa or within ± 1 percent of this pressure, whichever is greater. Measure the time to failure within ± 2 percent of 40 hours whichever is smaller. Analyze the test results by using for each specimen, the logarithm of the stress/strain in kPa/cm/cm and logarithm of the time-to-failure in hours as described in **F-11** to **F-15**. Calculate the long term hydrostatic stress/strain at 100 000 hours.

F-5.5.2 A specimen which leaks within one diameter of an end closure may be (1) included as a failure point if it lies above the 97.5 percent lower confidence limit curve, (2) repaired and testing resumed provided the leak is more than one diameter from a test joint, or (3) discarded and no failure point recorded.

F-5.5.3 Those test specimens that have been under test for more than 10 000 hours and had not failed may be included as failed points in the calculation procedures. This may reduce the long term hydrostatic stress/strain. Later, when these samples fail, a new long term hydrostatic stress/strain can be established using the actual failure time.

F-5.5.4 Determine the final line for extrapolation by the method of least squares using the failure points along with those non-failure points selected by the method described in **F-5.5.3**. Do not use failure points for stress/strain or pressures that cause failure in less than 0.3 h on the average. Determine these points by averaging the times to failure at tests made at the same stress or pressure level, i.e. a stress within ± 1 380 kpa or a pressure within ± 138 kPa. Include in the report all failure points excluded from the calculation by this operation and identify them as being in this category.

F-5.6 Determine suitability of the data for obtaining LTHS of the pipe as follows.

F-5.6.1 Calculate the lower confidence limit of stress/strain at 100 000 hours by the method given in **F-12**.

F-5.6.2 If the lower confidence value differs from the extrapolated value of LTHS by more than 15% or the M calculated in **F-12** is zero or negative or the slope '*b*', of the regression line calculated in **F-11** is positive, consider the data unsuitable.

F-6 HYDROSTATIC DESIGN BASIS

F-6.1 Calculate the LTHS in accordance with **F-5**.

F-6.2 Calculate the hydrostatic strength '*f*', at 50 years (438 000 h), as follows:

$$h = a + bf$$

where, '*a*' and '*b*' are values calculated as per **F-11.3**, and h = 5.641 5.

F-6.3 Obtain HDB from the applicable hydrostatic strength, as specified below:

i) Use the values calculated in **F-6.1**, if it is less than 125% of the 50-year value (**F-6.2**), and

ii) Use the value calculated in **F-6.2**, if it is less than 80% of LTHS (**F-6.1**).

F-6.4 Determine the HDB category in accordance with Table 8.

F-7 SUMMARY OF METHOD B

F-7.1 When a piping product has an existing HDB determined in accordance to Method A, any significant change in material, manufacturing process, construction or liner thickness will necessitate a requalification as described in **F-7.2** to **F-7.6**.

F-7.2 Obtain failure points for at least two sets of specimens, each set consisting of three or more specimens tested at the same stress/strain or pressure level, that is a stress/strain within ± 1 380 kPa/± 0.000 15 cm/cm or a pressure ± 138 kPa as follows:

Hours to Failure (Average of Set)	*Failure Points*
10 to 200	Atleast 3
More than 1 000	Atleast 3
Total	Atleast 6

Include as failure those specimens which have not failed after 3 000 hours. Provided they exceed the existing HDB regression line.

F-7.3 Calculate and plot the 95 percent confidence limit and 95 percent prediction limit of the original regression line in accordance with **F-13** using only data obtained prior to the change.

NOTE – Prediction limit defines the upper and lower bounds for single observations, whereas confidence limit defines upper and lower bounds for the main regression line.

F-7.4 Consider any changes in material or manufacturing process permissible if the results of **F-7.2** meet the criteria in **F-7.4.1**, **F-7.4.2** and **F-7.4.3**.

F-7.4.1 The average failure point for each stress/strain or pressure level falls on or above the 97.5 percent lower confidence limit of the original regression line.

F-7.4.2 The earliest individual failure point at each stress/strain or pressure level falls on or above the 97.5 percent lower prediction limit of the original regression line.

F-7.4.3 The failure point are distributed about the originally determined regression line. No more than two-third of the individual failure points may fall below the original regression line.

F-7.5 (Alternative to F-7.4)

Consider any changes in material or manufacturing process permissible if the results of **F-7.2** meet **F-7.5.1** and **F-7.5.2**.

F-7.5.1 All data points fall above the 97.5 percent lower confidence limit of the regression line.

F-7.5.2 At least two points exceed 3 000 hours without failure.

Table 8 Hydrostatic Design Basis Categories

Hydrostatic Design Basis Category kPa	Range of Calculated Values kPa
17 200	16 500 - 20 700
21 700	20 800 - 26 300
27 600	26 400 - 33 000
34 500	33 100 - 40 900
43 400	41 000 - 52 900
55 200	53 000 - 65 900
68 900	66 000 - 82 900
86 200	83 000 - 105 900
110 000	106 000 - 130 900
138 000	131 000 - 169 900
172 000	170 000 - 209 900
217 000	210 000 - 259 900
276 000	260 000 - 320 000

F-7.6 Data meeting the criteria of **F-7.4** or **F-7.5** may be assumed to be part of the original data set and a new regression line and HDB determined using all failure points.

F-7.7 If the data fails to satisfy the criteria of **F-7.4** or **F-7.5** the changes are considered significant and a new regression line shall be established. While the new test programme is being conducted as per Method A, an interim HDB for the material or process change may be taken as per the lower of **F-7.7.1** and **F-7.7.2**.

F-7.7.1 The 97.5 percent lower confidence limit of the value obtained by extrapolating the failure points of **F-7.2** to 438 000 hours by the procedure given in **F-6.2**.

F-7.7.2 The 97.5 percent lower confidence limit of the original regression line at 438 000 hours (50 years).

F-8 HYDROSTATIC DESIGN STRESS/STRAIN

F-8.1 Obtain the hydrostatic design stress/strain (HDS) by multiplying the hydrostatic design basis (HDB) as determined by Method A or Method B, whichever is appropriate by a service (design) factor as recommended in **F-2.7**.

F-9 PRESSURE RATING

F-9.1 Calculate the pressure rating for each diameter and wall thickness of pipe (*see* **7.4**) from the hydrostatic design stress/strain, for the specific material in the pipe by means of the formula

$$PN = \frac{HDS \times 2tr}{(D - tr)}$$

where notations are as defined in **F-2.2**.

F-10 REPORT

The report shalll include the following:

a) Complete identification of the sample, including material type, source, manufacturer's name and code number, and previous significant history, if any;
b) Pipe dimensions including nominal size, average and minimum wall thickness and average inside/outside diameter, and liner material and liner thickness, if pipe is lined;
c) Test temperature;
d) Test environment inside and outside of the pipe to be kept at ambient temperature;
e) A table of time-to-failure, in hours, and corresponding stress/strain level in kPa/cm/cm of all the specimens tested and the nature of the failures. Specimens that are designated as failures after they have been under stress/strain for more than 10 000 hours shall be indicated;
f) The estimated long term hydrostatic stress/strain (LTHS);
g) The mean stress/strain at long time 5.641 55 and lower confidence value;
h) The hydrostatic design basis (HDB);
i) The source of the hydrostatic design basis, that is Method A or Method B;
j) Any unusual behaviour observed in the tests;
k) Dates of tests; and
l) Name of laboratory and supervisor of tests.

F-11 LEAST SQUARES CALCULATIONS FOR LONG TERM STRESS/STRAIN

F-11.1 The following symbols are used (*see also* Note):

N = Number of points on the time-to-failure versus stress/strain plot;
f = logarithm of failure stress/strain, percent;
F = arithmetic average of all 'f' values;
h = logarithm of failure time in hours; and
H = arithmetic average of all 'h' values.

NOTE – All logarithms are to the base 10. Use 5 place tables for calculations.

F-11.1.1 The equation of the straight line is:

$$h = a + b.f$$

F-11.2 Compute the three quantities:

$$U = \Sigma f^2 - NF^2$$

$$V = \Sigma h^2 - NH^2$$

$$W = \Sigma f h - NFH$$

F-11.3 Calculate 'a' and 'b' as follows:

$b = W/U$ and $a = H - bF$

If 'b' is positive, the data are unsuitable for evaluating the material.

F-11.3.1 Substitute these values of 'a' and 'b' into the equation $h = a + bf$.

F-11.3.2 Arbitrarily select three convenient values for 'f' and calculate 'h' for each. The values of 'f' *should not be chosen too close to one another. Plot these three pairs of values for* 'f' and 'h'. If these three points do not lie on a straight line, there is a mistake in the calculations.

F-11.3.3 A sample of calculations is given in **F-15**.

F-12 CALCULATIONS FOR LOWER CONFIDENCE LIMIT

F-12.1 Let f_{100000} represent the value of the stress/strain corresponding to 100 000 hours failure time. Then $f_{100\,000} = (5 - a)/b$

F-12.2 The lower confidence value of the stress/strain at 100 000 hours is given by the following calculations.

F-12.2.1 Calculate $D = 5 - H$

F-12.2.2 Calculate the variance $s^2 = [1/(N - 2)] [V - (W^2/U)]$ and its square root 's', the standard variation.

F-12.2.3 Substitute the value 't' of Student's 't' distribution from Table 9 corresponding to N-2 degrees of freedom at the two-sided 5 percent level of significance.

Table 9 Statistical Data

(*Clause* F-12.2.3)

Degree of Freedom N-2	Student's 't'	Degree of Freedom N-2	Student's 't'	Degree of Freedom N-2	Student's 't'
1	12.706 2	46	2.012 9	91	1.986 4
2	4.302 7	47	2.011 7	92	1.986 1
3	3.182 4	48	2.010 6	93	1.985 8
4	2.776 4	49	2.009 6	94	1.985 5
5.	2.570 6	50	2.008 6	95.	1.985 3
6	2.446 9	51	2.007 6	96	1.985 0
7	2.364 6	52	2006 6	97	1.984 7
8	2.306 6	53	2.005 7	98	1.984 5
9	2.262 2	54	2.004 9	99	1.984 2
10	2.228 1	55	2.004 0	100	1.984 0
11	2.201 0	56	2.003 2	102	1.993 5
12	2.178 8	57	2.002 5	104	1.983 0
13	2.160 4	58	2.001 7	106	1.982 6
14	2.144 8	59	2.001 0	108	1.982 2
15	2.131 5	60	2.000 3	110	1.981 8
16	2.119 9	61	1.999 6	112	1.981 4
17	2.109 8	62	1.999 0	114	1.981 0
18	2.100 9	63	1.998 3	116	1.980 6
19	2.093 0	64	1.999 7	118	1.980 3
20	2.086 0	65	1.997 1	120	1.979 9
21	2.079 6	66	1.996 6	122	1.979 6
22	2.073 9	67	1.996 0	124	1.979 3
23	2.068 7	68	1.995 5	126	1.979 0
24	2.063 9	69	1.994 9	128	1.978 7
25	2.059 5	70	1.994 4	130	1.978 4
26	2.055 5	71	1.993 9	132	1.978 1
27	2.051 8	72	1.993 5	134	1.977 8
28	2.048 4	73	1.993 0	136	1.977 6
29	2.045 2	74	1.992 5	138	1.977 3
30	2.042 3	75	1.992 1	140	1.977 1
31	2.039 5	76	1.991 7	142	1.976 8
32	2.036 9	77	1.991 3	144	1.976 6
33	2.034 5	78	1.990 8	146	1.976 3
34	2.032 2	79	1.990 5	148	1.976 1
35	2.030 1	80	1.990 1	150	1.975 9
36	2.028 1	81	1.989 7	200	1.971 9
37	2.026 2	82	1.989 3	300	1.967 9
38	2.024 0	83	1.989 0	400	1.965 9
39	2.022 7	84	1.988 6	500	1.964 7
40	2.021 1	85	1.988 3	600	1.963 9
41	2.019 5	86	1.987 9	700	1.963 4
42	2.018 1	87	1.987 6	800	1.962 9
43	2.016 7	88	1.987 3	900	1.962 6
44	2.015 4	89	1.987 0	1 000	1.962 3
45	2.011 1	90	1.986 7	Infinity	1.960 0

F-12.2.4 Calculate the quantity : $M = b^2 - (t^2 . s^2/U)$

F-12.2.4.1 If 'M' is negative or zero, the slope of log time versus stress/strain is not significantly different from zero. In this case, the data are unreliable for the evaluation of the material. The calculations below should be carried out only when the value of 'M' is positive.

F-12.2.5 Calculate the quantity:

$$L = [bD - ts\sqrt{(D^2/U) + (M/N)}]/M$$

F-12.2.6 The lower confidence limit of $f_{100\,000}$ is equal to $L + F$.

NOTE – There is a 97.5 percent probability that new mean value for the regression line will be above the lower confidence limit.

F-13 CALCULATIONS AND CURVE PLOT OF 95 PERCENT CONFIDENCE LIMITS AND 95 PERCENT PREDICTION LIMITS

F-13.1 At any assigned logarithmic value for stress/strain (f_o) the 95 percent confidence limits for the corresponding lograithmic value of time (h_{CL}) is obtained from:

$$h_{CL} = (a + bf_o) \pm ts\,[\,(f_o - F)^2/U + 1/N\,]^{0.5}$$

NOTE – Curves representing the 95 percent confident limits may also be calculated and plotted by repetition of the calculation procedures in **F-12** by substituting various logarithmic values for 'h' (given as 5 in **F-12.1**) and replacing the minus sign in the expression for 'L' with a plus or minus signs shown in Eq 18 of **F-14**.

F-13.2 At any assigned logarithmic value of stress/strain (f_o) the 95 percent prediction limits for the corresponding logarithmic value of time (h_{PL}) is obtained from:

$$h_{PL} = (a + bf_o) + ts\,[(f_o - F)^2/U + 1/N + 1\,]^{0.5}$$

NOTE – 97.5 percent of the expected failures at the selected logarithmic value for stress/strain f_o will occur after the lower h_{PL}. The average failure time at f_o will be longer than the lower h_{CL} 97.5 percent of the time.

F-14 DERIVATION OF FORMULAS

F-14.1 The basic equation is :

$$h = a + bf + \text{error} \qquad \text{........ (1)}$$

which can also be written:

$$h - H = b\,(f - F) + \text{error} \qquad \text{........(2)}$$

F-14.1.1 Consider the assigned value for 'h' (for example, $h = 5.0$) corresponding to a failure time of 100 000 hours. Denote it by h_o. The problem is to evaluate the uncertainty of the corresponding value f_o. The value of f_o is evaluated by the equation:

$$b\,(f_o - F) = h_o - H \qquad \text{.........(3)}$$

$$\text{Let } z = b\,(f_o - F) - (h_o - H) \qquad \text{.........(4)}$$

F-14.1.2 Then the expected value of 'z' is zero (because of Eq 3)

$$E\,(z) = 0 \qquad \text{........(5)}$$

and the variance of z $V(z)$ is given by:

$$V\,(z) = (f_o - F)^2\,V\,(b) + V\,(H) \qquad \text{.......(6)}$$

F-14.1.3 By Least Square's Theory we know that :

$$V\,(H) = \sigma^2/N \qquad \text{.......... (7)}$$

$$\text{and } V\,(b) = \sigma^2/(f - F)^2 = \sigma^2/U \qquad \text{.......(8)}$$

where

σ^2 = variance of the error in the determination of any single 'h' value.

F-14.2 Introducing Eq 7 and 8 into Eq 6 gives:

$$V\,(z) = \sigma^2\,[(f_o - F)^2/U + (1/N)] \qquad \text{........ (9)}$$

F-14.3 The estimate for σ^2 is:

$$s^2 = [1/(N-2)]\,[V - (W^2/U)] \qquad \text{....(10)}$$

and is evaluated with (N-2) degrees of freedom, consequently, an estimate for V (z) is given by:

$$V\,(z) = [1/(N-2)]\,[V - (W^2/U)]\,[\{(f_o - F)^2/U\} + (1/N)]$$

$$= s^2\,[\{(f_o - F)^2/U\} + (1/N)] \qquad \text{....(11)}$$

and the estimated standard deviation of 'z' is:

$$s_z = s\sqrt{[\,\{(f_o - F)^2/U\} + (1/N)]}$$

F-14.4 The quantity $[z - E\,(z)/s_z$ has Student's t-distribution with (N -2) degree of freedom.

F-14.5 Let t denote the critical value of Student's t, for (N-2) degree of freedom and for chosen level of significance. Then the following inequity hold with probability equal to the applicable confidence coefficient:

(1 – level of significance):

$$-t \le [\,\{z - E\,(z)\}\,/s] \le +t \qquad \text{....(12)}$$

which is equivalent to :

$$[\,\{z - E\,(z)\}^2/V\,(z)] \le t^2 \qquad \text{....(13)}$$

F-14.6 The limits of the interval are given by:

$$[z - E\,(z)]^2 = t^2\,V\,(z) \qquad \text{.......(14)}$$

which in view of Eq 5 and 11, becomes:

$$z^2 = t^2\,s^2\,[\,\{(f_o - F)^2/U)\} + (1/N)] \qquad \text{........(15)}$$

F-14.7 Introducing Eq 4, Eq 15 can be written:

$$[b\,(f_o - F) - (h_o - H)]^2 = t^2\,s^2\,[\,\,\{f_o - F)^2/U)\,\,\} + (1/N)] \qquad \text{.......(16)}$$

F-14.8 Writing

$L = (f_o - F)$ ....(17a)

$D = (h_o - H)$ ....(17b)

and solving Eq 16 for L, we obtain:

$$L = \frac{bD \pm ts\sqrt{[b^2 - (t^2 . s^2/U)]/N + (D^2/U)}}{b^2 - (t^2 . s^2/U)} \quad ......(18)$$

F-14.9 Let $M = b^2 - (t^2 . s^2/U)$ ....(19)

F-14.9.1 Then, the lower limit for L is given by :

$$L \text{ Power limit} = \frac{bD - ts\sqrt{(D^2/U) + (M/N)}}{M} \quad ...(20)$$

F-14.10 Consequently, in view of the Eq 17a, the lower limit for f_o is given by:

f_o, Power limit = Lower limit + F

F-15 SAMPLE CALCULATION ACCORDING TO F-12

Typical sample calculations for strain and for stress methods are given in **F-15.1** and **F-15.2** respectively.

F-15.1 Strain Method

Data Point	Time (hours)	Strain (%)	Log Time (h)	Log Strain (f)
1	25.9	1.151	1.413 30	0.061 08
2	34.7	1.125	1.540 33	0.051 15
3	260.4	1.077	2.415 64	0.032 22
4	424.3	1.041	2.627 67	0.017 45
5	95.3	1.028	1.979 09	0.011 99
6	157.1	1.027	2.196 18	0.011 57
7	46.7	0.911	1.669 32	– 0.040 48
8	124.7	0.902	2.095 87	– 0.044 79
9	766.8	0.885	2.884 68	– 0.053 06
10	1 064	0.880	3.026 94	– 0.055 52
11	1 013	0.879	3.005 61	– 0.056 01
12	2 770	0.794	3.442 48	– 0.100 18
13	12 408	0.768	4.093 70	– 0.114 64
14	4 981	0.747	3.697 32	– 0.126 68
15	3 780	0.706	3.577 49	– 0.151 20
16	4 427	0.699	3.646 11	– 0.155 20
17	28 272	0.678	4.451 36	– 0.168 77
18	16 943	0.657	4.228 99	– 0.182 44

Data Point	h^2	f^2	f
1	1.997	0.003 730	0.086 317
2	2.372 62	0.002 617	0.078 793
3	5.835 32	0.001 038	0.077 822
4	6.904 65	0.000 305	0.045 855
5	3.916 80	0.000 144	0.023 735
6	4.823 21	0.000 134	0.025 410
7	2.786 63	0.001 639	- 0.067 577
8	4.392 67	0.002 006	- 0.093 880
9	8.321 38	0.002 815	- 0.153 052
10	9.162 37	0.003 082	- 0.168 047
11	9.033 69	0.003 137	- 0.168 347
12	11.850 67	0.010 036	- 0.344 864
13	16.758 38	0.013 142	- 0.469 298
14	13.670 18	0.016 048	- 0.468 373
15	12.798 44	0.022 860	- 0.540 899
16	13.294 12	0.024 187	- 0.567 054
17	19.814 61	0.028 483	- 0.751 256
18	17.884 36	0.033 283	- 0.771 516

$\Sigma h = 51.992\ 08$ $\quad \Sigma f = 1.063\ 82$ $\quad H = 2.888\ 45$ $\quad F = 0.059\ 10$ $\quad N = 18$

$(\Sigma h)^2 = 2\ 703.175\ 87$ $\quad (\Sigma f)^2 = 1.311\ 72$ $\quad \Sigma h^2 = 165.617\ 45$ $\quad \Sigma f^2 = 0.168\ 69$ $\quad \Sigma fh = 4.226\ 23$

Step 1:

$U = 0.168\,69 - 1.311\,72/18 = 0.105\,81$

$V = 165.617\,45 - 2703.175\,87/18 = 15.441\,02$

$W = -4.226\,23 - (-1.063\,82 * 51.992\,08/18) = -1.153\,44$

Step 2:

$b = W/U = -1.153\,44/0.105\,81 = -10.900\,79$

$a = H - bf = 2.888\,45 - (-10.900\,79 * 0.059\,10) = 2.244\,20$

Step 3:

$H = 2.244\,20 - 10.900\,79 * f$

Step 4:

Selected Strain (%)	f	h	Calculated Time (hrs)
1.0	0	2.244 20	175.50
0.8	– 0.096 91	3.300 60	1 998
0.6	– 0.221 85	4.662 53	45 976

A plot of strain versus time on log-log graph paper or of 'f' versus 'h' on regular graph paper shows that the three points lie on a straight line. Thus, the calculations are correct.

Step 5 :

Calculate strain at 100 000 hours and at 438 000 hours (50 years) from the equation in Step 3.

$$5 = 2.244\,20 - 10.900\,79\,f$$

or $-10.900\,70\,f = 2.755\,8$ or $f = -0.252\,81$

Strain at 100 000 hours = 0.558 7

$$5.641\,77 = 2.244\,20 - 10.900\,79\,f$$

or $-10.900\,79\,f = 3.397\,571$ or $f = -0.311\,68$

Strain at 50 years = 0.487 9

F-15.2 Stress Method

Data Point	Time (hours)	Stress (kPa)	Log Time (h)	Log Stress (f)
1	9	37 415	0.954 24	4.573 04
2	13	37 415	1.113 94	4.573 04
3	17	37 415	1.230 45	4.573 04
4	142	35 374	2.152 29	4.548 68
5	209	35 374	2.320 15	4.548 68
6	446	34 013	2.649 33	4.531 64
7	589	32 635	2.770 12	4.513 92
8	684	34 013	2.835 06	4.531 64
9	1 299	32 635	3.113 61	4.513 92
10	1 301	31 972	3.114 28	4.504 77
11	1 430	32 635	3.155 34	4.513 92
12	2 103	32 635	3.322 84	4.513 92
13	2 230	29 932	3.348 30	4.476 13
14	4 110	31 972	3.613 84	4.504 77
15	5 184	29 932	3.714 66	4.476 13
16	8 900	31 292	3.949 39	4.495 43
17	10 920	30 612	4.038 22	4.485 89
18	12 340	30 612	4.091 32	4.485 89

Data Point	h^2	f^2	fh
1	0.910 57	20.912 69	4.363 77
2	1.240 86	20.912 69	5.094 09
3	1.514 00	20.912 69	5.626 90
4	4.632 35	20.690 49	9.790 08
5	5.383 09	20.690 49	10.553 62
6	7.018 98	20.535 76	12.005 81
7	7.673 56	20.375 47	12.504 10
8	8.037 57	20.535 16	12.847 47
9	9.694 57	20.375 47	14.054 58
10	9.698 74	20.292 95	14.029 11
11	9.956 17	20.375 47	14.242 95
12	11.041 27	20.375 47	14.999 03
13	11.211 11	20.035 74	14.987 43
14	13.059 84	20.292 95	16.279 51
15	13.798 70	20.035 74	16.627 30
16	15.597 68	20.208 89	17.754 20
17	16.307 22	20.123 21	18.115 01
18	16.738 90	20.123 21	18.353 21

$\Sigma h = 51.487\ 83$ $\Sigma f = 81.364\ 457$ $\Sigma fh = 232.009\ 55$

$\Sigma h^2 = 163.515\ 167$ $\Sigma f^2 = 367.805\ 14$ $N = 18$

$(\Sigma h)^2 = 2\ 650.95$ $(\Sigma f)^2 = 6\ 620.173\ 7$

$H = h/N = 2.860\ 41$ $F = f/N = 4.520\ 25$

Step 1:

$U = \Sigma f^2 - NF^2 = 367.805\ 14 - 367.787\ 13 = 0.017\ 71$

$V = \Sigma h^2 - NH^2 = 163.515\ 16 - 147.275\ 02 = 16.240\ 14$

$W = \Sigma fh - NFH = 232.009\ 953 - 232.735\ 49 = -0.726\ 16$

Step 2:

$b = W/U = -0.726\ 16/0.017\ 71 = -41.002\ 82$

$a = H - b_f = 2.860\ 41 + 185.343\ 01 = 188.203\ 42$

Step 3:

$H = 188.203\ 42 - 41.002\ 82 * f$

Step 4:

Selected Stress (kPa)	*f*	*h*	*Calculated Time* (hrs)
30 000	4.477 12	4.628 87	42 548
32 000	4.505 17	3.470 07	3 010
34 000	4.531 48	2.399 96	251

A plot of stress versus time on log-log graph paper or of '*f*' versus '*h*' on regular graph paper shows that the three points lie on a straight line. Thus, the calculations are correct.

Step 5:

Calculate stress at 100 000 hours and at 438 000 hours (50 years) from the equation in Step 3.

Period	*Stress* (kPa)
100 000 hours	29 381
50 years	28 342

ANNEX G

(*Clause* 17.1)

SAMPLING AND FREQUENCY AND CRITERIA FOR CONFORMITY

G-1 ACCEPTANCE TESTS

G-1.1 One pipe selected at random from a lot (*see* **G-1.2**) shall be checked for conformance to the dimensions (**7**), workmanship (**9**), stiffness (**10**), longitudinal strength test (**13**), and hoop tensile strength (**14**). Additional tests establishing potability of water mentioned in **16.2**, **16.3**, **16.5** and **16.8** shall be done as acceptance tests on the sample pipe.

The lot shall be declared as conforming to the requirements of this specification, if the sample pipe meets the requirements of all the tests, otherwise not.

G-1.2 Unless otherwise agreed upon between the purchaser and the supplier, one lot shall consist of 100 lengths or part thereof, of same pressure class, stiffness class, and size of pipes produced under relatively uniform composition and condition of manufacture.

G-2 TYPE TEST

G-2.1 Sampling for type test is not required unless otherwise agreed upon between the manufacturer and the purchaser. Test certificates shall be furnished when requested by the purchaser, for the following:

i) Long term hydrostatic design pressure test (**15**), and
ii) Tests establishing potability of water, including
   a) acidity and alkalinity (**16.4**),
   b) UV absorbing material (**16.6**),
   c) heavy metals (**16.7**), and
   d) biological (**16.9**).

G-2.2 Type tests shall be performed whenever a significant change is made in the design, composition or process of manufacture. Even if no change is envisaged, the frequency of the type test shall be at least once in three years.

ANNEX A
(Foreword)

COMMITTEE COMPOSITION

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