diameter) and relative roughness (d/k). For Reynolds number greater than 10^7, the friction factor 'f' (and hence the C value) is relatively independent of diameter and velocity. However, for normal ranges of Reynolds number of 4000 to 10^6 the friction factor 'f' (and hence the C value) do depend on Diameter, Velocity and relative roughness.

PVC, Glass Reinforced Plastic (GRP) and other plastic pipes are inherently more smooth compared to Asbestos Cement (AC), Concrete and cement mortar/epoxylined metallic pipes. Depending on quality of workmanship during manufacture and the manufacturing process, the AC, Concrete and cement mortar/epoxylined metallic pipes tend to be as smooth as PVC, GRP and other plastic pipes.

The metallic pipes lined with cement mortar or epoxy and Concrete pipes behave as smooth pipes and have shown C values ranging from 140 to 145 depending on diameter and velocity. Reference may be made to " Manual of Water Supply Practices", AWWA/M9 published by American Water Works Association (AWWA), second edition 1995.

With a view to reduce corrosion, increase smoothness, and prolong the life of pipe materials, the metallic pipes are being provided with durable smooth internal linings. AC, Concrete and cement mortar/epoxylined metallic pipes, PVC, GRP and other plastic pipes may not show any significant reduction in their carrying capacity with age and therefore the design roughness coefficient values (C values) should not be substantially different from those adopted for new pipes.

However, pipes carrying raw water are susceptible to deposition of silt and development of organic growth resulting in reduction of carrying capacity of such pipes. In case of buildup of substantial growth /buildup of deposits in such pipes, they can be removed by scraping and pigging the pipelines. Reference may be made to Chapter 10 section 10.3 of this manual ('Preventive maintenance- cleaning of pipes').

Unlined metallic pipes under several field conditions such as carrying waters having tendency for incrustation and corrosion, low flow velocity and stagnant water and alternate wet and dry conditions (resulting from intermittent operations), undergo substantial reduction in their carrying capacity with age. Therefore lower 'C" values have been recommended for design of unlined metallic pipes. As such, use of unlined metallic pipes should be discouraged.

The values of the Hazen-Williams coefficient 'C' for new conduit materials and the values to be adopted for design purposes are shown in Table 6.1.

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Table 6.1: HAZEN - WILLIAMS COEFFICIENTS

Pipe Material	Recommended C Values	
	New Pipes@	Design Purpose
Unlined Metallic Pipes		
Cast Iron, Ductile Iron	130	100
Mild Steel	140	100
Galvanized Iron above 50 mm dia. #	120	100
Galvanized Iron 50 mm dia and below used for house service connections. #	120	55
Centrifugally Lined Metallic Pipes		
Cast Iron, Ductile Iron and Mild Steel Pipes lined with cement mortar or Epoxy		
Up to 1200 mm dia	140	140
Above 1200 mm dia	145	145
Projection Method Cement Mortar Lined Metallic Pipes		
Cast Iron, Ductile Iron and Mild Steel Pipes	130*	110**
Non Metallic Pipes		
RCC Spun Concrete,		
Prestressed Concrete		
Up to 1200 mm dia	140	140
Above 1200 mm dia	145	145
Asbestos Cement	150	140
PVC, GRP and other Plastic pipes.	150	145

@ *The C values for new pipes included in the Table 6.1 are for determining the acceptability*

of surface finish of new pipelines. The user agency may specify that flow test may be conducted for determining the C values of laid pipelines.

\# *The quality of galvanizing should be in accordance with the relevant standards to ensure resistance to corrosion through out its design life.*

* *For pipes of diameter 500 mm and above; the range of C values may be from 90 to 125 for pipes less than 500mm..*

** *In the absence of specific data, this value is recommended. However, in case authentic field data is available, higher values upto 130 may be adopted.*

The coefficient of roughness for use in Manning's formula for different materials as presented in Table 6.2 may be adopted generally for design purposes unless local experimental results or other considerations warrant the adoption of any other lower value for the coefficient. For general design purposes, however, the value for all sizes may be taken as 0.013 for plastic pipes and 0.015 for other pipes.

Table 6.2 : MANNING'S COEFFICIENT OF ROUGHNESS

Type of lining	Condition	n
Glazed coating of enamel Timber	In perfect order	0.010
	(a) Plane boards carefully laid	0.014
	(b) Plane Boards inferior workmanship or aged,	0.016
	(c) Non-plane boards carefully laid	0.016
	(d) Non-plane boards inferior workmanship or aged	0.018
Masonry	(a) Neat cement plaster	0.013
	(b) Sand and cement plaster	0.015
	(c) Concrete, Steel troweled	0.014
	(d) Concrete, wood troweled	0.015
	(e) Brick in good condition	0.015
	(f) Brick in rough condition	0.017
	(g) Masonry in bad condition	0.020
Stone work	(a) Smooth, dressed ashlar	0.015
	(b) Rubble set in cement	0.017
	(c) Fine, well packed gravel	0.020
Earth	(a) Regular surface in good condition	0.020
	(b) In ordinary condition	0.025
	(c) With stones and weeds	0.030

Type of lining	Condition	n
	(d) In poor condition	0.035
	(e) Partially obstructed with debris or weeds	0.050
Steel	(a) Welded	0.013
	(b) Riveted	0.017
	(c) Slightly tuberculated	0.020
	(d) Cement Mortar lined	0.011
Cast Iron & Ductile Iron	(a) Unlined	0.013
	(b) Cement mortar lined	0.011
Asbestos Cement		0.012
Plastic (smooth)		0.011

Note : *Values of n may be taken as 0.015 for unlined metallic pipes and 0.011 for plastic and other smooth pipes.*

The friction factor values in practice for commonly used pipe materials are given in Table 6.3.

TABLE6.3: RECOMMENDED FRICTION FACTORS IN DARCY-WEISBACH FORMULA

Sl. No	Pipe Material	Diameter(mm)		Friction Factor	
		From	To	New	For Design Period of 30 Years
1.	R.C.C.	100	2000	0.01 to 0.02	0.01 to 0.02
2.	A.C	100	600	0.01 to 0.02	0.01 to 0.02
3.	HDPE/PVC	20	100	0.01 to 0.02	0.01 to 0.02
4.	SGSW	100	600	0.01 to 0.02	0.01 to 0.02
5.	C.I. (for corrosive waters)	100	1000	0.01 to 0.02	0.053 to 0.03
6.	C.I (for non-corrosive waters)	100	1000	0.01 to 0.02	0.034 to 0.07
7.	Cement Mortar or Epoxy Lined metallic pipes (Cast Iron, Ductile Iron, Steel)	100	2000	0.01 to 0.02	0.01 to 0.02
8.	G.I.	15	100	0. 014 to 0.03	0.0315 to 0.06

(Reference may be made to I.S. 2951 for calculation of Head Loss due to friction according to Darcy-Weisbach formula).

6.2.3 HAZEN-WILLIAMS FORMULA

The commonly used Hazen-Williams formula has following inherent limitations:

(i) The numerical constant of Hazen-Williams formula (1.318 in FPS units or 0.85 in MKS units) has been calculated for an assumed hydraulic radius of 1 foot and friction slope of 1/1000. However, the formula is used for all ranges of diameter and friction slopes. This practice may result in an error of upto ± 30% in the evaluation of velocity and ± 55% in estimation of frictional resistance head loss.

(ii) The Darcy-Weisbach formula is dimensionally consistent. The Hazen-Williams coefficient C is usually considered independent of pipe diameter, velocity of flow and viscosity. However to be dimensionally consistent and to be representative of friction conditions, it must depend on relative roughness of pipe and Reynold's number. A comparison between estimates of Darcy-Weisbach friction factor f, and its equivalent value computed from Hazen-Williams C for different pipe materials brings out the error in estimation of 'f' upto ±45% in using Hazen Williams formula. It has been observed that for higher 'C' values (new and smooth pipes) and larger diameters, the error is less, whereas it is appreciable for lower 'C' values (old and rough pipes) and lower diameters at higher velocities.

(iii) The Hazen-Williams formula is dimensionally inconsistent, since the Hazen-Williams C has the dimension of $L^{0.37}\ T^{-1}$ and therefore is dependent on units employed.

6.2.3.1 Discussion On Various Formulae For Estimation Of Frictional Resistance

(i) With a view to avoid the limitations of the Hazen Williams formula, the present trend is to use the Colebrook-White equation for estimation of friction factors and then use the Darcy-Weisbach formula for estimation of head-loss due to friction in the pipelines. This practice will yield correct results compared to the Hazen Williams formula.

The estimation of Darcy's 'f' for variations in velocity and diameter involves repetitive and tedious calculations. Further, there is a need for assuming a correct k value in the Colebrook-White equation for calculation of friction coefficient 'f' in the Darcy-Weisbach formula. Conservative assumption of 'k' values will also result in under-utilization of carrying capacity of the pipes. However it is recommended that frictional losses should be estimated with Darcy-Weisbach formula by changing 'f' values for varying velocity and diameter combinations and assuming a correct k value in the Colebrook-White equation.

Recommended 'k' values for use in Colebrook-White formula are shown in 6.2.1 (d).

(ii) If there is a choice for use of pipe friction formulae, Darcy-Wiesbach yields accurate results but involves extra computational effort and therefore Hazen-Williams (HW) formula is commonly used. The Modified Hazen Williams (MHW) formula being an improvement was suggested for use in lieu of HW formula. The MHW formula shown in Para 6.2.4 is derived from Darcy-Weisbach (DW) and Colebrook- White equations. Since the friction coefficient depends on relative roughness of pipe and Reynolds number; C_R values also have to be varied for various diameter and velocity combinations to give correct estimation of the frictional resistance which also results in extra computational efforts. Average C_R values are given in Table 6.4 for use in the Modified Hazen Williams formula which will estimate frictional resistance within ±5% accuracy as per Table 6.4. Darcy-Weisbach formula coupled with Colebrook-White equation gives most accurate results followed by modified Hazen-Williams formula and Hazen-Williams formula.

(iii) It is significant to note that irrespective of the formula used for estimation of frictional resistance, it is necessary to adopt different roughness coefficient values for the various velocity-diameter combinations if the frictional resistance is to be accurately estimated involving changing the C values, k or `f` or C_R values for the same pipe material. In design, various velocity-diameter combinations are required.

6.2.4 MODIFIED HAZEN-WILLIAMS FORMULA

The Modified Hazen Williams formula has been derived from Darcy-Weisbach and Colebrook-White equations and obviates the limitations of Hazen-Williams formula.

$$V = 3.83\, C_R d^{0.6575} (gs)^{0.5525} / \nu^{0.105} \qquad (6.8)$$

Where,

C_R = coefficient of roughness

d = pipe diameter

g = acceleration due to gravity

s = friction slope

ν = viscosity of liquid

For circular conduits, ν_{20^0C} for water = 10^{-6} m²/s and g = 9.81 m/s²

The Modified Hazen Williams formula derived as

$$V = 143.534\, C_R\, r^{0.6575}\, S^{0.5525} \qquad (6.9)$$

$$h = [L(Q/C_R)^{1.81}]/994.62D^{4.81} \qquad (6.10)$$

in which,

V = velocity of flow in m/s;

C_R = pipe roughness coefficient; (1 for smooth pipes; <1 for rough pipes);

r = hydraulic radius in m;

s = friction slope;

D = internal diameter of pipe in m;

h = friction head loss in m;

L = length of pipe in m; and

Q = flow in pipe in m^3/s.

A nomograph for estimation of head loss by Modified Hazen-Williams formula is presented in the Appendix. 6.3.

6.2.5 Effect of Temperature on Coefficient of Roughness

Analysis carried out to evaluate effect of temperature (viscosity) on value of C_R reveals that the maximum variation of C_R for a temperature range of 10^0C to 30^0C is 4.5% for a diameter of 2000 mm at a velocity of 3.0 m/s. In the light of this revelation, C_R values are presented for average temperature of 20^0C.

6.2.6 Experimental Estimation of C_R Values

The coefficients of roughness in various pipe formulae are based on experiments conducted over a century ago. The values of Hazen Williams C, Mannings n and roughness k values in Moody's Diagram have also been used on experimental data collected in early nineteenth century. There have since been major advances in pipeline technology. Both the manufacturing processes and jointing methods have improved substantially over the years and newer pipe materials have come into use. Continued usage of roughness coefficients estimated without recognition of these advances is bound to result in conservative design of water supply systems. Accordingly C_R values of commonly used commercial pipe materials have been experimentally determined in a study conducted within the country. This study covered pipe diameters 100 to 1500 mm over a wide range of Reynold's Numbers (3×10^4 to 1.62×10^6) encountered in practice. The results indicate that centrifugally spun CI, RCC, AC and HDPE pipes behave as hydraulically smooth when new and hence, $C_R = 1$ for these pipes.

The use of Hazen Williams 'C' as per Table 6.1 results in under utilization of above pipe material when new. The extent of under utilization varies from 13 to 40 percent for CI pipes; 23 percent for RCC and AC pipes; and 8.4 percent for HDPE and PVC pipes.

6.2.7 Reduction in Carrying Capacity of Pipes with Age

The values of Hazen-Williams 'C' are at present arbitrarily reduced by about 20 to 23

percent in carrying capacity of pipes with age. Studies have revealed that chemical and bacteriological quality of water and velocity of flow affect the carrying capacity of pipes with age. The data on existing systems in some cities have been analyzed along with the experimental information gathered during the study to bring out a rational approach to the reduction in carrying capacity of pipes with age.

The C_R values obtained in such studies have shown that, except in the case of CI and steel pipes while carrying corrosive water, the current practice of arbitrary reduction in 'C' values as per Sec. 6.2.2 results in under utilization of pipe material to the extent of 38 to 71 percent for CI pipes for non-corrosive water; 46 to 93 percent for RCC pipes and 25 to 64 percent for AC and HDPE pipes.

6.2.8 Design Recommendations for use of Modified Hazen-Williams Formula

The following design recommendations are made to ensure effective utilization of pipe carrying capacity.

(i) New CI, DI, Steel, RCC, AC and HDPE pipes behave as hydraulically smooth and hence CR of 1 is recommended.

(ii) For design period of 30 years, no reduction in CR needs to be effected for RCC, AC, PVC and HDPE pipes irrespective of the quality of water. However, care must be taken to ensure self-cleansing velocity to prevent formation of slimes and consequent reduction in carrying capacity of these pipes with age.

(iii) For design period of 30 years, 15 percent reduction is required for unlined CI and DI pipes if non-corrosive water is to be transported. The design must also ensure self-cleansing velocity.

(iv) While carrying corrosive waters, unlined CI, DI, and steel pipes will loose 47 and 27 percent of their capacity respectively over a design period of 30 years. Hence, a cost trade-off analysis must be carried out between chemical and bio-chemical correction of water quality, provision of a protective lining to the pipe interiors and design at reduced CR value for ascertaining the utility of CI, DI and steel pipe material in the transmission of corrosive waters.

Recommended CR values are presented Table 6.4. The use of the recommended values in conjunction with Modified Hazen-Williams formula or the nomograph will permit fuller utilization of pipe materials.

TABLE 6.4

RECOMMENDED C_R VALUES IN MODIFIED HAZEN-WILLIAMS FORMULA (AT 20°C)

Sl. No.	Pipe Material	Diameter(mm)		Velocity(m/s)		C_R Value When New	C_R Value For Design Period of 30 Years
		From	To	From	To		
1.	RCC	100	2000	0.3	1.8	1.00	1.00
2.	AC	100	600	0.3	2.0	1.00	1.00

		Diameter(mm)		Velocity(m/s)			
3.	HDPE and PVC	20	100	0.3	1.8	1.00	1.00
4.	CI/DI (for water with positive Langelier's index)	100	1000	0.3	1.8	1.00	0.85*
5.	CI/DI (For waters with negative Langelier's index)	100	1000	0.3	1.8	1.00	0.53*
6.	Metallic pipes lined with cement mortar or epoxy (for water with negative Langelier's index)	100	2000	0.3	2.1	1.00	1.00
7.	SGSW	100	600	0.3	2.1	1.00	1.00
8.	GI (for waters with positive Langeliers Index)	15	100	0.3	1.5	0.87*	0.74

**These are average C_R values which result in a maximum error of ± 5% in estimation of surface resistance.*

6.2.9 Resistance due to Specials and Appurtenances

Pipeline transitions and appurtenances add to the head loss, which is expressed as velocity head as $K V^2/ 2g$ where V and g are in m/s and m/sec^2 respectively or equivalent length of straight pipe. The values of K to be adopted for different fittings are given in Table 6.5 and equivalent length of pipe for different sizes of various fittings with K=1 are given in Table 6.6.

TABLE 6.5 : K-VALUES FOR DIFFERENT FITTINGS

Type of Fitting	Value of K
Sudden contractions	0.3* - 0.5
Entrance shape well rounded	0.5
Elbow 90^0	0.5 - 1.0
45^0	0.4 - 0.75
22^0	0.25 - 0.50
Tee 90^0 take-off	1.5
Straight run	0.3

Type of Fitting	Value of K
Coupling	0.3
Gate valve (open)	0.3** - 0.4
With reducer and increaser	0.50
Globe	10.0
Angle	5.0
Swing check	2.5
Venturi Meter	0.3
Orifice	1.0

*Varying with area ratios.

**Varying with radius ratios.

TABLE 6.6 : EQUIVALENT LENGTH OF PIPE FOR DIFFERENT SIZES OF FITTINGS WITH K = 1

Size in mm	Equivalent length of pipe in metres	Size in mm	Equivalent length of pipe in metres
10	0.3	65	2.4
15	0.6	80	3.0
20	0.75	90	3.6
25	0.9	100	4.2
32	1.2	125	5.1
40	1.5	150	6.0
50	2.1		

6.2.10 GUIDELINES FOR COST EFFECTIVE DESIGN OF PIPELINES

The cost of transmission and distribution system constitutes a major portion of the project cost. It is desirable to adopt the following guidelines:

(i) The design velocity should not be less than 0.6 m/s in order to avoid depositions and consequent loss of carrying capacity.

(ii) In design of distribution systems, the design velocity should not be less than 0.6 m/s to avoid low velocity conditions which may encourage deposition and/or corrosion resulting in deterioration in quality. However, where inevitable due to minimum pipe diameter criteria or other hydraulic constraints, lower velocities may be adopted with adequate provision for scouring.

(iii) In all hydraulic calculations, the actual internal diameter of the pipe shall be

adopted after accounting for the thickness of lining, if any, instead of the nominal diameter or outside diameters (OD).

(iv) In providing for head loss due to fittings, specials and other appurtenances, actual head loss calculations based on consideration included in subsection 6.2.9 should be done instead of making an arbitrary provision.

6.3 PIPE MATERIALS

Pipelines are major investments in water supply projects and as such constitute a major part of the assets of water authorities. Pipes represent a large proportion of the capital invested in water supply undertakings and therefore are of particular importance. Therefore pipe materials shall have to be judiciously selected not only from the point of view of durability, life and over all cost which includes, besides the pipe cost, the installation and maintenance costs necessary to ensure the required function and performance of the pipeline throughout its designed life time.

6.3.1 CHOICE OF PIPE MATERIALS

The various types of pipes used are:

I. Metallic pipes : C.I., D.I., M.S., G.I.

(i) Unlined Metallic pipes

(ii) Metallic pipes lined with cement mortar or epoxy lining;

II. Non Metallic pipes

(i) Reinforced Concrete, Prestressed Concrete, Bar Wrapped Steel Cylinder Concrete, Asbestos Cement

(ii) Plastic Pipes : PVC, Polyethylence, Glass Reinforced Plastic, etc.

The determination of the suitability in all respects of the pipes and specials, for any work is a matter of decision by the Engineer concerned on the basis of requirements for the scheme.

Several technical factors affect the final choice of pipe material such as internal pressures, coefficient of roughness, hydraulic and operating conditions, maximum permissible diameter, internal and external corrosion problems, laying and jointing, type of soil, special conditions, etc.

Selection of pipe materials must be based on the following considerations:

(a) The initial carrying capacity of the pipe and its reduction with use, defined, for example, by the Hazen-Williams coefficient C.

Values of C vary for different conduit materials and their relative deterioration in service. They vary with size and shape to some extent.

(b) The strength of the pipe as measured by its ability to resist internal pressures and

external loads.

(c) The life and durability of pipe as determined by the resistance of cast iron and steel pipe to corrosion; of concrete and A.C. pipe to erosion and disintegration and plastic pipe to cracking and disintegration.

(d) The ease or difficulty of transportation, handling and laying and jointing under different conditions of topography, geology and other prevailing local conditions.

(e) The safety, economy and availability of manufactured sizes of pipes and specials.

(f) The availability of skilled personnel in construction and commissioning of pipelines.

(g) The ease or difficulty of operations and maintenance.

The life and durability of the pipe depends on several factors including inherent strength of the pipe material, the manufacturing process along with quality control, handling, transportation, laying and jointing of the pipeline, surrounding soil conditions and quality of water. Normally, the design period of pipelines is considered as 30 years. Where the pipelines have been manufactured properly as per specifications, designed and installed with adequate quality control and strict supervision, some of them have lasted more than the designed life provided the quality of water is non-corrosive. However, pipeline failures for various pipe materials even before the expiry of the designed life have been reported probably due to lack of rigid quality control during manufacture and installation, improper design, presence of corrosive waters, corrosive soil environment, improper bedding and other relevant factors.

Lined metallic pipelines are expected to last beyond the normal design life of 30 years. However, the relative age of such pipes depends on the thickness and quality of lining available for corrosion. The cost of the pipe material and its durability or design life are the two major governing factors in the selection of the pipe material. The pipeline may have very long life but may also be relatively expensive in terms of capital and recurring costs and, therefore, it is very necessary to carryout a detailed economic analysis before selecting a pipe material.

The metallic pipes are being provided with internal lining either with cement mortar or epoxy so as to reduce corrosion, increase smoothness and prolong the life.

Underground metallic pipelines may require protection against external corrosion depending on the soil environment and corrosive ground water. Protection against external corrosion is provided with cement mortar guiniting or hot applied coal-tar asphaltic enamel reinforced with fibreglass fabric yarn.

The determination of the suitability in all respects of the pipeline for any work is a matter of decision by the engineer concerned on the basis of the requirements for the scheme. A checklist in Table 6.7 for selection of pipe material has been provided to facilitate the decision makers in selecting the economical and reliable pipe material for the given conditions.

TABLE 6.7 : CHECK LIST FOR SELECTION OF PIPE MATERIAL

SNo	Attribute	Type of Pipes											Remarks if any
		PVC	AC	CI	DI	MS	PSC	GRP	HDPE	HUME	GI	OTHERS	
1	Hydraulic smoothness (C Value)												
2	Structural strength for external loads												
3	Strength to sustain internal pressure												
4	Ease in handling, transportation and storage												
5	Capacity to withstand damage in handling and maintenance												
6	Resistance to internal corrosion												
7	Resistance to external corrosion												
8	Resistance to heat/sunlight												
9	Resistance to rodent attack												
10	Sustainabilty in Black Cotton Soil												
11	Reliabilty and effective joints												
12	Capable to absorb surge pressure												
3	Ease in maintenance and repairs												
14	Use experience												
15	Durabilty (Sustainable trouble free maintenance)												
16	Consumer satisfacation												
17	Resistance to tampering by anti-social elements												
18	Economy												
19	Availability of specials												
20	Availability of skilled personnel for installation & maintenace												
21	Behaviour of pipe line – likelihood of interruptions due to leakage, bursting etc; and time for repairs												
	Recommended size range for												
	Rising Main												
	Gravity Main												
	Distribution Main												

Note : Weightage - 0 to 10 numbers in relation to the significance of the attributes (10 stands for highest quality) may be considered.

Use of this checklist is strongly recommended for large and medium projects (more than 15 Mld). The checklist can be filled up based on the merits and demerits of relevant pipe materials. It is necessary that a quantitative and qualitative assessment is made to arrive at the most economical and reliable pipe material.

The project report should include provisions for addressing the less favourable attributes along with the cost estimates for the same. Risk factors should be identified and stated clearly in the project report. Risk analysis should be carried out to arrive at the correct decision in selecting the pipe material.

6.3.2 CHECK LIST FOR SPECIFICATIONS FOR MANUFACTURE, SUPPLY, LAYING, JOINTING, TESTING AND COMMISSIONING OF PIPELINES

6.3.2.1 GENERAL

Water utilities often procure pipes from one manufacturer/supplier under one contract, procure the valves and fittings from another manufacturer/supplier under another contract and have them installed under another contract rather than entrusting the entire work of Manufacture, Supply, Laying, Jointing, Testing and Commissioning of pipelines to a single agency. This procedure is resorted to on the plea that it results in economy and saves time.

It is seen that wherever single contracts are not awarded for the entire work of Manufacture, Supply, Laying, Jointing, Testing and Commissioning of pipelines to a single agency, the responsibility for performance of the pipelines could not be assigned to any particular agency. Time delays if any, in procurement of fittings and valves will also affect the completion of the contract and also results in cost overruns. Quite often, at the time of commissioning, deficiencies are noticed which might be due to failure at the manufacturing stage or due to transportation handling, or laying/jointing defects or failure of fittings and valves.

Hence it is desirable that all pipeline contracts are awarded on a single contract responsibility so that quality assurance at various stages of manufacture, supply, delivery, laying, jointing and testing is taken care of by a single agency and the timely completion also rests with a single agency; this may result in receipt of competitive offers and hence results in economy. Further, the water utility's time and resources which otherwise are spent in monitoring the performance of several small contracts can be better utilised for quality management of the contract. This may ensure economy by timely completion and quality construction.

However it is necessary that the specifications for single contract responsibility have to be comprehensive and provide for penalty in delays so that the time and cost over runs can be avoided. There will be several site specific conditions and circumstances for the pipeline installations which vary to such an extent that it is very difficult to recommend a simple/ single all inclusive set of specifications for the pipeline contracts. A check list for drafting

specifications for Manufacture, Supply, Laying, Jointing, Testing and commissioning of pipelines for procurement through a single agency is furnished. Judicious selection of items which cover cross country or city installations is required.

6.3.3 CHECK LILST FOR SPECIFICATIONS FOR MANUFACTURE, SUPPLY, LAYING, JOINTING, TESTING AND COMMISSIONING PIPELINES

PART I PROCUREMENT

Section 1 - General

1.1 Scope of work

1.2 Definitions of client, contractor, engineer etc.

1.3 Drawings and documents referred to

1.4 Reference Standards

1.5 Penal clauses for failure to meet the time schedule & performance standards and requirements.

1.6 Basis for Prices; to include all pipes, fittings, valves, jointing materials, including labour, cost of factory testing, lining, coating, marking and all other incidental expenses for manufacture, transportation, insurance and delivery at site. (any exclusions/inclusions may be clearly specified)

Section 2 - Detailed Requirements - Pipes

2.1 Material for pipes (standards for materials), manufacturing operations, testing and inspection

2.2 Diameter of pipe

2.3 Wall thickness/other dimensions of the pipe

2.4 Class of pipe

2.5 Laying length

2.6 Pipe ends-flanged-socket/spigot/plain

2.7 Special pipe lengths and special fittings

2.8 Working Pressures

2.9 Pipe lining and coating both for buried and exposed pipes

Section 3 - Transportation and delivery at site

3.1 Type of trucks used for transportation-length/weight

3.2 Handling equipment for loading and unloading

Section 4 - Field Joints for Pipes

4.1 Requirements for machined couplings/ends

4.2 Flanged/joints, pitch circle, blots type, gasket quality

4.3 Welded joints-runs-thickness

PART II INSTALLATION

Section 1 - Instruction to Bidders

1.1 Procedure for invitation of bids

1.2 Instructions to bidders

1.3 Bidders proposal to include plan/programme for construction

1.4 Agreement and performance bonds

Section 2 - General Specifications

2.1 Definitions

2.2 Scope of Work

2.3 Payment conditions

2.4 Statutory Requirements- Payment of wages-Policy-Environment control-safety

2.5 Personnel

Section 3 - Detailed Specifications

3.1 Time Schedule

3.2 Construction facilities - Right of way - storage space - interference with other services

3.3 Work and materials

3.4 Concrete

3.5 Excavation - Bracing of excavation - Safety to public - Disposal of excess material from excavation

3.6 Maintenance, removal and reconstruction of other interfering facilities

3.7 Safeguarding of excavations and protection of property

3.8 Backfill

3.9 Resurfacing of roads within city and outside

Section 4 - Pipes

4.1 Approval of drawings for laying

4.2 Distribution along trench

4.3 Preparation of bedding

4.4 Lowering and laying

4.5 Jointing

4.6 Inspection and tests

4.7 Bends, manholes, outlets

4.8 Joints- Flanged , bolting materials and gasket- machined ends - welded joints

4.9 Field touch up of site joints.

6.4 CAST IRON PIPES

6.4.1 GENERAL

Most of the old Cast Iron pipes were cast vertically but this type has been largely superceded by centrifugally spun cast iron type manufactured upto a diameter of 1050 mm(IS- 1536-1989). Though the vertically cast iron pipe is heavy in weight, low in tensile strength, and liable to defects of inner surface, it is widely used because of its good lasting qualities. There are many examples of cast iron mains in this country which continue to give satisfactory service even after a century of use.

Cast Iron pipes and fittings are being manufactured in this country for several years. Due to its strength and corrosion resistance, C.I. pipes can be used in corrosive soils and for waters of slightly aggressive character. They are well suited for pressure mains and laterals where tapings are made for house connections. It is preferable to have coating inside and outside of the pipe.

Vertically cast iron pipes shall conform to I.S. 1537-1976. The pipes are manufactured by vertical casting in sand moulds. The metal used for the manufacture of this pipe is not less than grade 15. The pipes shall be stripped with all precautions necessary to avoid wrapping or shrinking defects. The pipes shall be such that they could be cut, drilled or machined.

Cast Iron flanged pipes and fittings are usually cast in the larger diameters. Smaller sizes have loose flanges screwed on the ends of double spigot-spun pipe.

The method of Cast Iron pipe production used universally today is to form pipes by spinning or centrifugal action. Compared with vertical casting in sand moulds, the spun process results in faster production, longer pipes with vastly improved metal qualities, smoother inner surface and reduced thickness and consequent lightweight(IS. 1536 –1989).

Centrifugally cast iron pipes are available in diameters from 80mm to 1050mm and are covered with protective coatings. Pipes are supplied in 3.66m and 5.5m lengths and a variety of joints are available including socket and spigot and flanged joints.

The pipes have been classified as LA, A and B according to their thicknesses. Class LA pipes have been taken as the basis for evolving the series of pipes. Class A allows a 10% increase in thickness over class LA. Class B allows a 20% increase in thickness over class LA.

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The pipes are spigot and socket type. When the pipes are to be used for conveying potable water, the inside coating shall not contain any constituent soluble in water or any ingredient which could impart any taste or odour whatsoever to the potable water, after sterilization and suitable washing of the main.

Experiments in centrifugal casting of iron pipes were started in 1914 by a French Engineer which ultimately resulted in commercial production of spun pipes. Spun pipes are about 3/4 of the weight of vertically cast pipes of the same class. The greater tensile strength of the spun iron is due to close grain allowing use of thinner wall than for that of a vertically Cast Iron pipe of equal length. It is possible by this process to increase the length of the pipe whilst a further advantage lies in the smoothness of the inner surface.

6.4.2 Laying And Jointing

Before laying the pipes, the detailed map of the area showing the alignment, sluice valves, scour valves, air valves and fire hydrants along with the existing intercepting sewers, telephone and electric cables and gas pipes will have to be studied. Care should be taken to avoid damage to the existing sewer, telephone and electric cables and gas pipes. The pipeline may be laid on the side of the street where the population is dense. Pipes are laid underground with a minimum cover of 1 metre on the top of the pipe.

Laying of cast iron pipes for water supply purposes has been generally governed by the regulations laid down by the various municipalities and corporations. These regulations are intended to ensure proper laying of pipes giving due consideration to economy and safety of workers engaged in laying.

6.4.2.1 Excavation And Preparation Of Trench

Excavation may be done by hand or by machine. The trench shall be so dug that the pipe may be laid to the required gradient and at the required depth. When the pipeline is under a roadway a minimum cover of 1.0 m is recommended. The width of the trench at bottom shall provide not less than 200mm clearance on both sides of the pipe. Additional width shall be provided at positions of sockets and flanges for jointing. Depths of pits at such places shall also be sufficient to permit finishing of joints.

6.4.2.2 Handling Of Pipes

While unloading, pipes shall not be thrown down but may be carefully unloaded on inclined timber skids. Pipes shall not be dragged over other pipes and along concrete and similar pavements to avoid damage to pipes.

6.4.2.3 Detection Of Cracks In Pipes

The pipes and fittings shall be inspected for defects and be rung with a light hammer, preferably while suspended, to detect cracks. Smearing the outside with chalk dust helps in

the location of cracks. If doubt persists further confirmation may be obtained by pouring a little kerosene on the inside of the pipe at the suspected spot. If a crack is present the kerosene seeps through and shows on the outer surface. Any pipe found unsuitable after inspection before laying shall be rejected.

6.4.2.4 Lowering Of Pipes And Fittings

All pipes, fittings, valves and hydrants shall be carefully lowered into the trench by means of derrick, ropes or other suitable tools and equipment to prevent damage to pipe materials and protective coatings and linings. Pipes over 300mm dia shall be handled and lowered into trenches with the help of chain pulley blocks.

6.4.2.5 Cleaning Of Pipes And Fittings

All lumps, blisters and excess coating material shall be removed from socket and spigot end of each pipe and outside of the spigot and inside of the socket shall be wire-brushed and wiped clean and dry and free from oil and grease before the pipe is laid.

After placing a length of pipe in the trench, the spigot end shall be centered in the socket and the pipe forced home and aligned to gradient. The pipe shall be secured in place with approved back fill material packed on both sides except at socket.

The socket end should face the upstream while laying the pipeline on level ground; when the pipeline runs uphill, the socket ends should face the up gradient. When the pipes run beneath the heavy loads, suitable size of casing pipes or culverts may be provided to protect the casing of pipe. High pressure mains need anchorage at dead ends and bends as appreciable thrust occurs which tend to cause draw and even "blow out" joints. Where thrust is appreciable concrete blocks should be installed at all points where movement may occur. Anchorages are necessary to resist the tendency of the pipes to pull apart at bends or other points of unbalanced pressure, or when they are laid on steep gradients and the resistance of their joints to longitudinal or shear stresses is either exceeded or inadequate. They are also used to restrain or direct the expansion and contraction of rigidly joined pipes under the influence of temperature changes. Anchor or thrust blocks shall be designed in accordance with I.S. 5330-1984.

6.4.3 JOINTS

Several types of joints such as rubber gasket joint known as Tyton joint, mechanical joint known as Screw Gland joint, and conventional joint known as Lead joint are used.

6.4.3.1 Categories Of Joints

Joints are classified into the following three categories depending upon their capacity for movement.

(a) Rigid joints

Rigid joints are those which admit no movement at all and comprise of flanged, welded and turned and bored joints. Flanged joints require perfect alignment and close fittings are

frequently used where a longitudinal thrust must be taken such as at the valves and meters. The gaskets used between flanges of pipes shall be of compressed fibre board or natural or synthetic rubber. Welded joints produce a continuous line of pipes with the advantage that interior and exterior coatings can be made properly and are not subsequently disrupted by the movement of joints.

(b) Semi Rigid joints

Semi rigid joint is represented by the spigot and socket with caulked lead joint. A semi rigid joint allows partial movement due to vibration etc. The socketed end of the pipe should be kept against the flow of water and the spigot end of the other pipe is inserted into this socket. A twisted spun yarn is filled into this gap and it is adjusted by the yarning tool and is then caulked well. A rope is then placed at the outer end of the socket and is made tight fit by applying wet clay, leaving two holes for the escape of the entrapped air inside. The rope is taken out and molten lead is poured into the annular space by means of a funnel. The clay is then removed and the lead is caulked with a caulking tool. Lead wool may be used in wet conditions. Lead covered yarn is of great use in repair work, since the leaded yarn caulked into place will keep back water under very low pressure while the joint is being made.

(c) Flexible joints

Flexible joints are used where rigidity is undesirable such as with filling of granular medium and when two sections cannot be welded. They comprise mainly mechanical and rubber ring joints or tyton joints which permit some degree of deflection at each joint and are therefore able to stand vibration and movement. In rubber jointing special type of rubber gaskets are used to connect cast iron pipe which are cast with a special type of spigot and socket in the groove, the spigot end being lubricated with grease and slipped into the socket by means of a jack used on the other end. The working conditions of absence of light, presence of water and relatively cool uniform temperature are all conducive to the preservation of rubber and consequently this type of joint is expected to last as long as the pipes. Hence, rubber jointing is to be preferred to lead jointing.

6.4.4 TESTING OF THE PIPELINE

6.4.4.1 General

After laying and jointing, the pipeline must be pressure tested to ensure that pipes and joints are sound enough to withstand the maximum pressure likely to be developed under working conditions.

6.4.4.2 Testing Of Pressure Pipes

The field test pressure to be imposed should be not less than the maximum of the following:

(a) 1 1/2 times the maximum sustained operating pressure.

(b) 1 1/2 times the maximum pipeline static pressure.