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Thermoplastics pipes for the transport of liquids under pressure — Calculation of head losses

Tubes en matières thermoplastiques pour le transport de liquides sous pression — Calcul des pertes de charge

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The main task of technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

— type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

— type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 10501, which is a Technical Report of type 3, was prepared by Technical Committee ISO/TC 138, *Plastics pipes, fittings and valves for the transport of fluids*, Sub-Committee SC 2, *Plastics pipes and fittings for water supplies.*

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Thermoplastics pipes for the transport of liquids under pressure — Calculation of head losses

1 Scope

This Technical Report gives a method of calculating head loss in the transport of liquids under pressure in hydraulically smooth thermoplastics pipes.

The formulae given in the Technical Report apply to the transport of water under pressure, or to all other liquids of the same dynamic viscosity, at temperatures of up to 45°C.

2 Definitions

For the purposes of this Technical Report, the following definitions apply.

2.1 flowrate, q_V : Volume of water flowing through the pipe per unit time.

2.2 steady flow : Flow in which the flowrate through a measuring section does not vary with time.

2.3 average velocity, v : Flowrate through the pipe divided by the reference cross-section of the pipe. It is calculated by dividing the actual flowrate through the pipe by the cross-section of the pipe.

2.4 reference cross-section of the pipe, A : Area of the circle with a diameter equal to the average internal diameter of the pipe. The free cross-sectional area of the pipe is calculated from the inside diameter of the pipe.

2.5 head loss, Δh : Change in pressure head between two sections of a horizontal pipe due to liquid flow through the pipe.

2.6 head drop, J : Head loss per unit length of pipe.

3 Symbols and units

The symbols and units used in this Technical Report are given in Table 1.

Table 1

Sub-clause	Quantity	Symbol	Unit
2.1	Flowrate	q_V	m³/h
2.3	Average velocity	v	m/s
2.4	Average internal diameter	d	m
2.5	Head loss	Δh	m
2.6	Head drop	J	m/m
4.1	Reynolds number	Re	dimension-less
4.1	Kinematic viscosity	ν	m²/s
4.2	Pipe length	l	m
4.3	Temperature of liquid	t	°C
4.3	Temperature correction factor	k_t	dimension-less

4 Method of calculation

4.1 Formulae for calculating head drop

4.1.1 The head drop for water, J_o, in metres per metre, at a temperature of 20°C, is calculated using one of the following formulae:

4.1.1.1 Where the Reynolds number[1)] lies within the range

$4 \times 10^3 \leq Re < 1{,}5 \times 10^5$:

$$J_o = 5{,}37 \times 10^{-4}\left(d^{-1{,}24} v^{1{,}76}\right)$$

4.1.1.2 Where the Reynolds number[1)] lies within the range

$1{,}5 \times 10^5 \leq Re \leq 10^6$:

$$J_o = 5{,}79 \times 10^{-4}\left(d^{-1{,}20} v^{1{,}80}\right)$$

NOTE 1 – The various formulae generally used in calculating head loss in pipes are given in annex A.

4.1.2 The head drop J_x for a liquid x which differs from that of water is calculated by the following formula:

$$J_x = J_o\left(\frac{\nu_x}{\nu_w}\right)^b$$

where

J_x is the head drop for a specific liquid;

J_o is the head drop for water at a temperature of 20°C;

ν_x is the kinematic viscosity of a specific liquid at the desired temperature;

ν_w is the kinematic viscosity of water at a temperature of 20°C.

Exponent b has the following values:

a) when the Reynolds number lies within the range

$4 \times 10^3 \leq Re < 1{,}5 \times 10^5$:

$$b = 0{,}24$$

b) when the Reynolds number lies within the range

$1{,}5 \times 10^5 \leq Re \leq 10^6$:

$$b = 0{,}20$$

4.2 Formula for calculating head loss

The head loss Δh of a liquid column is calculated from the following formula:

$$\Delta h = Jl$$

4.3 Formula for temperature correction

The formulae for calculation of J given in 4.1 relate to the flow of water at a temperature of 20°C.

When the water temperature differs from 20°C, the value of J is determined by applying the following temperature correction formula :

$$J_t = k_t J_o$$

where J_t is the head drop at temperature t .

4.3.1 When the Reynolds number lies within the range

$4 \times 10^3 \leq Re < 1{,}5 \times 10^5$,

the k_t values given in Table 2 should be taken.

1) See formula for Reynolds number in annex A.

Table 2

Temperature of water (t) (°C)	Temperature correction factor (k_t)
0	1,148
5	1,105
10	1,067
15	1,033
20	1,000
25	0,972
30	0,947
35	0,925
40	0,904
45	0,885

4.3.2 When the Reynolds number lies within the range

$$1,5 \times 10^5 \leq Re \leq 10^6,$$

the k_t values given in Table 3 should be taken.

Table 3

Temperature of water (t) (°C)	Temperature correction factor (k_t)
0	1,122
5	1,087
10	1,055
15	1,027
20	1,000
25	0,977
30	0,956
35	0,937
40	0,919
45	0,903

NOTE 2 – For liquids other than water, it is not necessary to specify special methods for calculating J, since the formula given in 4.1.2 can also be used for variations in the temperature of the liquid. This is due to the fact that the temperature in the formula is expressed in the kinematic viscosity of the specific liquid at the desired temperature.

Annex A

Formulae used in calculations

This annex gives a number of formulae generally used for calculating head losses in pipes, caused by the flow of liquid.

The formulae given in A.1.1 to A.1.10 are generalized formulae applicable to all types of pipe. The formulae given in A.1.11 and A.1.12 were developed especially for plastics pipes.

A.1 Head loss formulae

A.1.1 Chezy formula

$$v = A\sqrt{r_h J}$$

where

v is the velocity;

r_h is the hydraulic radius;

J is the head drop;

A is the coeffieient.

A.1.2 Hagen and Poiseuille formula (in the metric system)

$$J = 32\left(\frac{v\nu}{g d_i^2}\right)$$

where

d_i is the internal diameter of the pipe;

ν is the dynamic viscosity;

g is the gravitational acceleration.

A.1.3 Reynolds number

$$Re = \frac{v d_i}{\nu}$$

A.1.4 Von Karman formula

$$\frac{1}{\sqrt{\lambda}} = 2 \log\left(\frac{2,51}{Re\sqrt{\lambda}}\right)$$

where λ is a function of the Reynolds number and of the relative roughness k/d where k is the roughness of the pipe wall.

A.1.5 Colebrook formula

$$\frac{1}{\sqrt{\lambda}} = -2 \log\left(\frac{k}{3,7d} + \frac{2,51}{Re\sqrt{\lambda}}\right)$$

where k is generally taken between 0,001 and 0,007 for plastics pipes.

A.1.6 Hazen-Williams formula (in the metric system)

$$J = 2,16 \times 10^7 \left(v^{-1,852} C^{-1,852} d^{-1,167}\right)$$

where C is the the Hazen-Williams coefficient, which depends on the roughness of the pipe.

A.1.7 Strickler formula (also known as the Manning-Strickler formula)

$$v = k r_h^{2/3} J^{1/2}$$

A.1.8 Scimemi formula (in the metric system)

$$v = 61,5\, d^{0,68} J^{0,56}$$

A.1.9 Blasius formula

$$\lambda = 0,3164\, Re^{-0,25}$$

A.1.10 Tison formula (in the metric system)

$$J = 0,000545\, v^{1,75} d^{-1,25}$$

or

$$v = 73,3\, d^{0,714} J^{0,571}$$

A.1.11 Formulae proposed by SII (Israel) for flow of water in plastics pipes (in the metric system)

(1) $J_o = 0,518 \times 10^{-3} \left(v^{1,76}\, d^{-1,24}\right)$

or

$$v = 73,6\, d^{0,705}\, J^{0,568}$$

for Reynolds number range

$4 \times 10^3 \leq Re < 1,5 \times 10^5$

(2) $J_o = 0,590 \times 10^{-3} \left(v^{1,81}\, d^{-1,119}\right)$

or

$$v = 60,8\, d^{0,618}\, J^{0,552}$$

for Reynolds number range

$1,5 \times 10^5 \leq Re \leq 10^6$

A.1.12 Formula proposed by SNV (Switzerland) for flow of water in plastics pipes (in the metric system)

$$J = \frac{\pi}{4}\left(kv^{1,75}\, d^{-1,25}\right)$$

or

$$v = k'\, d^{0,714}\, J^{0,571}$$

A.2 Formulae for plastics pipes proposed in this Technical Report

The formulae given in 4.1 proposed by France are almost identical to formulae A.1.10, A.1.11 and A.1.12 cited above.

The values for head losses for water flow in plastics pipes published in the technical literature are generally similar to those obtained from the formulae given in 4.1. In addition, it should be noted that laboratory test measurements of head losses in plastics pipes, such as PVC and polyethylene, have given results which are very close to those obtained by the theoretical calculcation when using the formulae proposed in 4.1.

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