New formulae and graphs for load losses calculation in the uplift pipes.

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Abstract

It is proved today practically all industries require fluid movement systems with different characteristics, adapted to the industrial processes placed in position. The complexity degree of fluid transport systems may therefore be variable.

The calculation of load losses in pipes remains of capital importance especially for the choice and the measurement of energy generators (pump etc…)

Our study, from an essentially numerical aspect, contribute to the determination of load losses in pipes. Absolute roughness : k = 2 mm; k = 1 mm; : k = 0,1 mm

Résumé

Il est établi aujourd'hui que pratiquement toutes les industries imposent la nécessité de réseaux pour le déplacement de fluides à caractéristiques diverses appropriés aux procédés industriels mis en place.
Le degré de complexité des réseaux de transport de fluide pour différents usages peut donc être variable.

Le calcul des pertes de charge dans les conduites sous pression demeure d'une importance capitale surtout pour le choix et le dimensionnement des générateurs d'énergie (pompes etc…).

Notre étude à aspect essentiellement numérique, contribue à la détermination des pertes de charge dans les conduites sous pression pour les rugosités les plus utilisées à savoir :
k = 2 mm ; k =1 mm et k = 0,1 mm .

INTRODUCTION :

The energy loss along a fluid current is due to the rubbings of the molecules between each other and against the walls of the solid appliance that guides the fluid. These rubbings are present as soon as there is a movement, since they result from the liquid viscosity and the speed turbulence.

The intrinsic complexity of the turbulence phenomenon characterises the majority of the real flows and gives a significant increase to the rubbing that wastes energy [1 ; 9].

The aim of our study leads us to give a practical formulation of energy losses calculation which gives only one maximum relative divergence of 1% in compare with that of Colebrook in a range of speeds between 0,4 m/s and 2,4 m/s

We must, first of all, precise that we have taken a temperature equal to 0°C as a labour base because it is the most unfavourable hypothesis because it has the maximal viscosity [1] .

PRACTICAL FORMULATION FOR LOAD LOSSES CALCULATION IN THE UPLIFT PIPES

To calculate a pump elevation height we have to know as accurately as possible about the load losses. These losses are, either local : they result from a direction change of the pipe or a modification of its section, or continuous (we frequently say linear). They are, however, related to the state of the chosen surface, characterised by its roughness [2 ; 4] .

The continuous load losses represent generally the essential of the total losses ; it is important, however, to make the minimal error on the physical characteristics assessment on which they depend [3]

General expression

$$J = M \cdot Q^{\beta} / D_{int}^{\alpha} \qquad (1)$$

This reduced expression is used for the grid networks calculation [5 ; 6] with :

M ; β ; α : invariants .

Q: flow in m^3/s .

$D_{int} = (D_{ext} - 2e)$: internal diameter in mm .

With :

D_{ext} : external diameter in mm .

e : pipe thickness in mm .

The expression (1) can be put under the following form :

$$J = r \cdot Q^2 \cdot \delta \cdot E \qquad (2)$$

With :

E : the physical coefficient considering thickness.

δ : The adjustment coefficient of the load loss [10 ; 11 ; 12].

r : Resistance coefficient of the internal wall of the pipe in s^2/m^6 .

It is constant for a roughness and a given diameter [9 ; 10 ; 11 ; 12].

Q : flow in m^3 / S.

The expressions (1) and (2) , for identical data, give us the same load losses. We propose them to the academicians and the experts to express their opinion .

Absolute roughness : k = 2 mm :

$$v / \nu \geq 2{,}79 \,.\, 10^5 \, m^{-1}$$

$$J = 0.001808 \, Q^{2} / D_{int}^{5{,}327}$$

Where: $j = r \,.\, Q^2 \,.\, \delta \,.\, E$

The value of the resistance coefficient will be calculated by the following formula:

$$r = 0{,}001808 / D_N^{5{,}327} \qquad (3)$$

Table 1 Resistance coefficient value: K = 2 mm

D_N (mm)	80	100	150	200	250	300	350	400
r (s^2/m^6)	1310,938	399,34	46,058	9,948	3,0350	1,1474	0,5048	0,2478

D_N (mm)	450	500	600	700	800	900	1 000
r (s^2/m^6)	0,1323	0,0755	0,02858	0,01257	0,006174	0,003297	0.001808

The geometrical coefficient value will be calculated by the following formula :

$$E = (D_N / D_{int})^{5.327} \qquad (4)$$

with :

D_N : nominal diameter that we also call standard, commercial or conditioned which in reality does not exist . It is the diameter to which we attribute a name. Following this method, it must be corrected by the geometrical coefficient given by the formula (4) .

In this case, the kinematic viscosity has no effect on the flow and the adjustment coefficient can only be equal to 1.

Absolute roughness : k = 1 mm

$$v / \nu \geq 5{,}58 \,.\, 10^5 \, m^{-1}$$

$$J = 0{,}001596 \, Q^2 / D_{int}^{5{,}327} \qquad (5)$$

$v / \nu < 5{,}58 \,.\, 10^5 \, m^{-1}$

$J = 0{,}00158 \, Q^{1{,}96} / D_{int}^{5{,}22}$ (6)

the resistance coefficient value will be calculated by the following formula :

$r = 0{,}001596 / D_N^{5.3}$ (7)

Table 2 Resistance coefficient value: K = 1 mm

D_N (mm)	80	100	150	200	250	300	350	400
r (s^2/m^6)	1039,097	318,444	37,123	8,083	2,477	0,9425	0,4165	0,2052

D_N (mm)	450	500	600	700	800	900	1 000
r (s^2/m^6)	0,1099	0,06288	0,02392	0,01057	0,005208	0,00279	0,001596

$J = r \, Q^2 \, \delta \, E$ (8)

Geometrical coefficient $E = (D_N / D_{int})^{5,.3}$

Adjustment coefficient values $\delta = 0.9713 \, [1 + 0.102/V]^{0,.3}$ (see table 3)

Table 3 Adjustment coefficient value

V (m/s)	0,20	0,25	0,30	0,35	0,40	0,50	0,60	0,70	0,80	0,90	≥1
δ	1,0991	1,0763	1,0604	1,0488	1,0398	1,0269	1,0181	1,0118	1,0069	1,0031	1,0

Absolute roughness : k = 0,1 mm

$0{,}4 < v \leq 2{,}4 \; m / s$

$J = r \,.\, Q^2 \,.\, \delta \,.\, E$ (9)

Resistance coefficient value will be calculated by the following formula (9)

$r = 0{,}00157 / D_N^{5{,}226}$ (10)

Table 4 Resistance coefficient value: K = 0.1mm

D_N (mm)	80	100	150	200	250	300	350	400
r s^2/m^6	1039,097	318,444	37,123	8,083	2,477	0,9425	0,4165	0,2052

D_N (mm)	450	500	600	700	800	900	1 000
r s^2/m^6	0,1099	0,06288	0,02392	0,01057	0,005208	0,00279	0,001596

Geometrical coefficient $E = (D_N / D_{int})^{5,226}$ (11)
The geometrical coefficient is introduced only when we are working with standard diameters.
Where δ is the adjustment coefficient of the flow system. We present its values in table n°1.

$$\delta = 0,8554 (1 + 0,996 / V)^{0,226} \quad (12)$$

where v speed in m / s .
Adjustment coefficient values (see table n°5)

Table 5 Adjustment coefficient values

V (m/s)	0.20	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	≥2.4
δ	1.281	1.135	1.067	1.027	1.00	0.981	0.966	0.954	0.945	0.937	0.931	0.925

VALIDITY FIELD

The values obtained from the general expressions (1) and (2) have been compared with those of Colebrook. The maximum relative divergence is about 1% in a range of speeds between 0.4 m / s and 2.4 m / s.

FORMULAE AND GRAPHS USE FOR DIFFERENT TEMPERATURES

In the case of a fluid which has a different kinematic viscosity from that used in the setting of the formulae (the fluid will be called base fluid), the below explanation allows the use of the formulae without having to resolve again in each particular case the equation in λ constituted by Colebrook formula .
The study that we have undertaken shows that for given values of K , and of D, λ depends only on the intercourse value V / ν .[4]
In all the following reasoning , K , D , and g stay, of course, without change .
ν_f : Fluid kinematic viscosity f which we look for its load loss .
ν_b : Base fluid kinematic viscosity ($\nu_b = 1,79 . 10^{-6} m^2 / s$)
V_f : Fluid average speed in the considered section .
V_b : Base fluid speed , such that the intercourse V/ν has the same value for both fluids (both expressed in m/s) .
J_f Fictitious fluid load loss .
J_b Base fluid load loss corresponding to that of V_b .

Both expressed in m of fluid considered by m of pipe, We know that λ will be the same for the fictitious flow and for the base fluid provider that we have :

$$v_f / \nu_f = v_b / \nu_b$$
$$v_b = v_f \ (\nu_b / \nu_f)$$
$$J_F / J_b = v_f^2 / v_b^2 = \nu_f^2 / \nu_b^2$$
$$J_f = J_b \ (\nu_f / \nu_b)^2$$

<u>Case study:</u>

Suppose a steel pipe of a 150 mm and a 3 mm thickness which vehicles a 20 l/s along 1 000 m length.

The aim is to determine the load losses considering that the absolute roughness is equal to K = 1 mm and the temperature equal to t° = 0° C.

<u>Solution</u> :

$$V = 4 \cdot Q / \pi D_N^2 = 4 \cdot 0{,}020/3{,}14 \cdot (0{,}15)^2 = 1{,}13 \text{ m/s.}$$
$$J_1 = (0{,}000984 \cdot V^2 / D_N^{1,3}) \cdot E_1$$

For a nominal diameter equal to 150 mm and with a 3 mm thickness, the geometrical coefficient value , if we suppose that the external diameter is equal to 159 mm, will be equal to :

$$E_1 = =(D_N / D_{int})^{5,3} = 150 / (159\text{-}2.3)^{5,3} = 0{,}900$$

The load loss J_1, when replacing all the parameters by their value, will be equal to :

$$J_1 = [0{,}000984 \cdot 1{,}13^2 / (0{,}15)^{1,3}] \cdot 0{,}9 = 0{,}0\ 1336 \text{ m/ml}$$

We can calculated this load loss by replacing the speed by the flow.

$$J_1 = (0{,}001596 \cdot Q^2 / D_N^{5,3}) \cdot E_1$$
$$J_1 = 0{,}001596 \cdot (0{,}02^2 / D_N^{5,3}) \cdot 0{,}9 = 0{,}0\ 1336 \text{ m/ml}$$

We can also use this formula by introducing directly in this latter the internal diameter. This diameter is calculated as follows :

$$D_{int} = D_{ext} - (2 e)$$

with :

- e : pipe thickness in mm (we take the thickness equal to 3 mm).
- D_{ext} : external diameter in mm (equal to 159 mm).
- D_{int} : internal diameter in mm.

$$D_{int} = 159 - (2 \cdot 3) = 153 \text{ mm}$$
$$J_1 = 0{,}001596 \cdot Q^2 / D_{int}^{5,3}$$
$$J_1 = 0{,}001596 \cdot 0{,}02^2 / 0{,}153^{5,3} = 0{,}01336 \text{ m/ml}$$

If we multiply the unit load loss by the total length of the pipe we will obtain :

$$J_1 = 0{,}01336 \cdot 1000 = 13{,}36 \text{ m}$$

We notice that the result is the same whatever is the formula that we use We either calculate the load loss directly with the internal diameter, by surpressing the geometrical coefficient, or we calculate it with the nominal diameter and we introduce the geometrical coefficient.

We conclude that the geometrical coefficient plays a corrector role.

FORMULATION UNDER THE FORM OF GRAPHS

We give under the form of graphs , the energy losses gradient for the absolute roughness : K= 2,0 mm ; K = 1,0 mm and K= 0,1mm.

Method of using

For many calculations, The precision of a Cartesian graph is sufficient, but its reading is often difficult. It can be used according to the following steps :

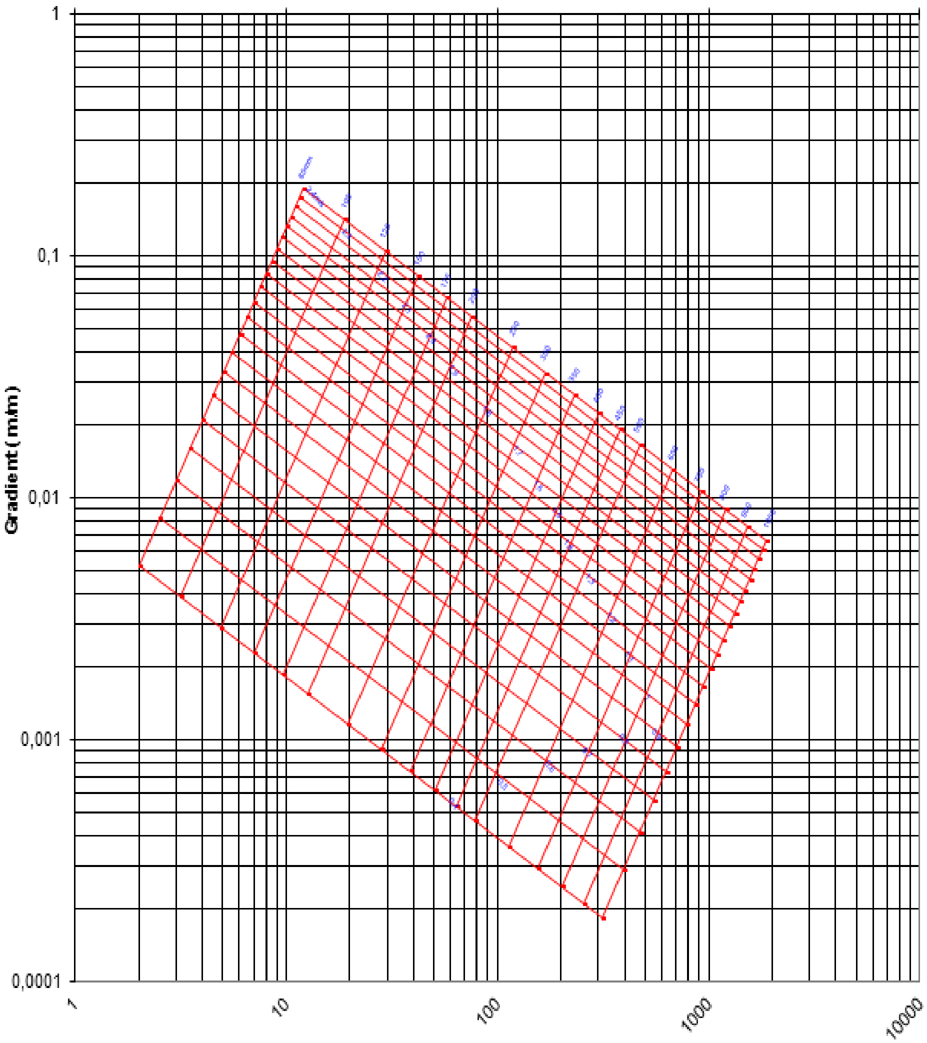
1°/ To identify the flow value in abscissa

2°/ To follow the vertical which corresponds to this value until a nominal diameter

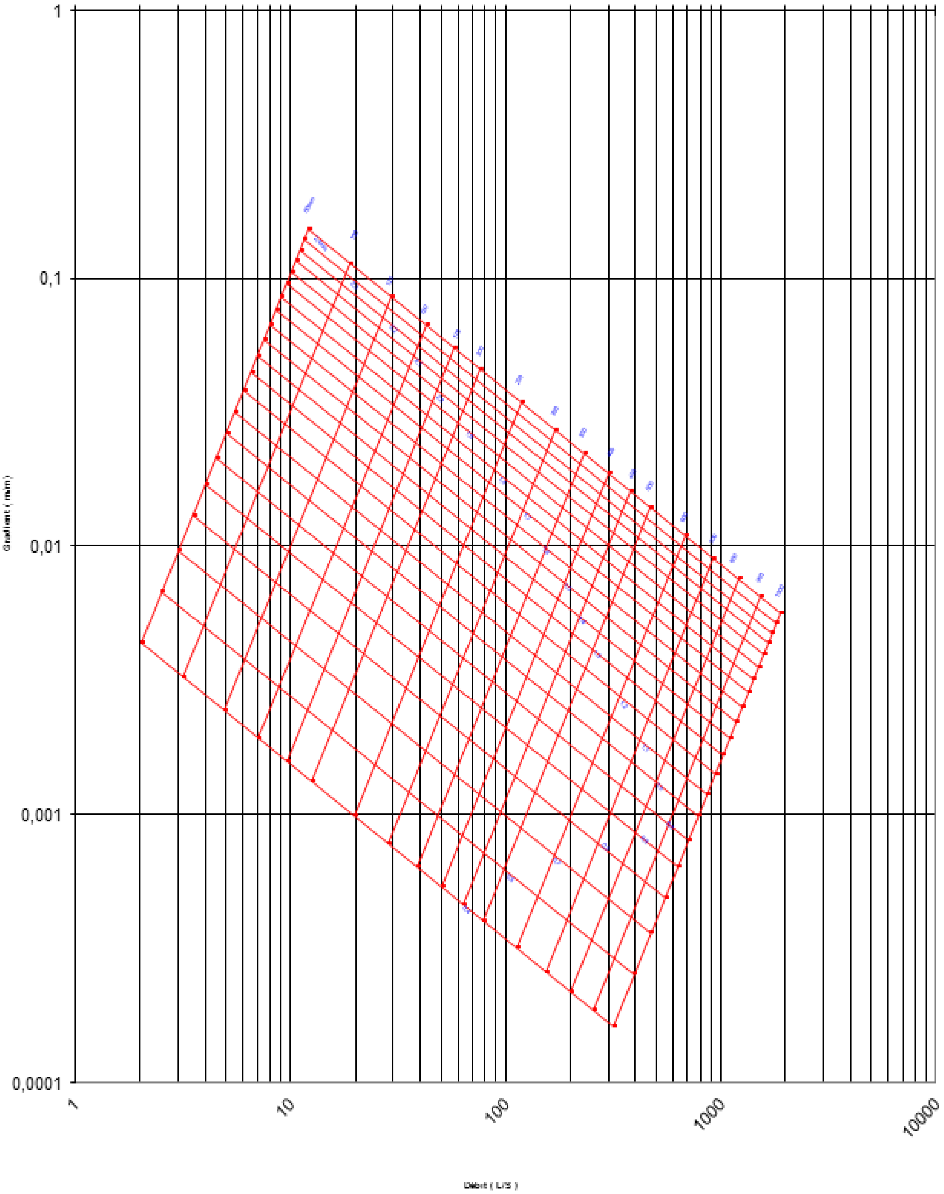
3°/ According to this point, the speed read on the obliques (V en m/s) .

4°/ According to this point, the load loss read on the horizontal is obtained with sufficient precision by a visual interpolation.

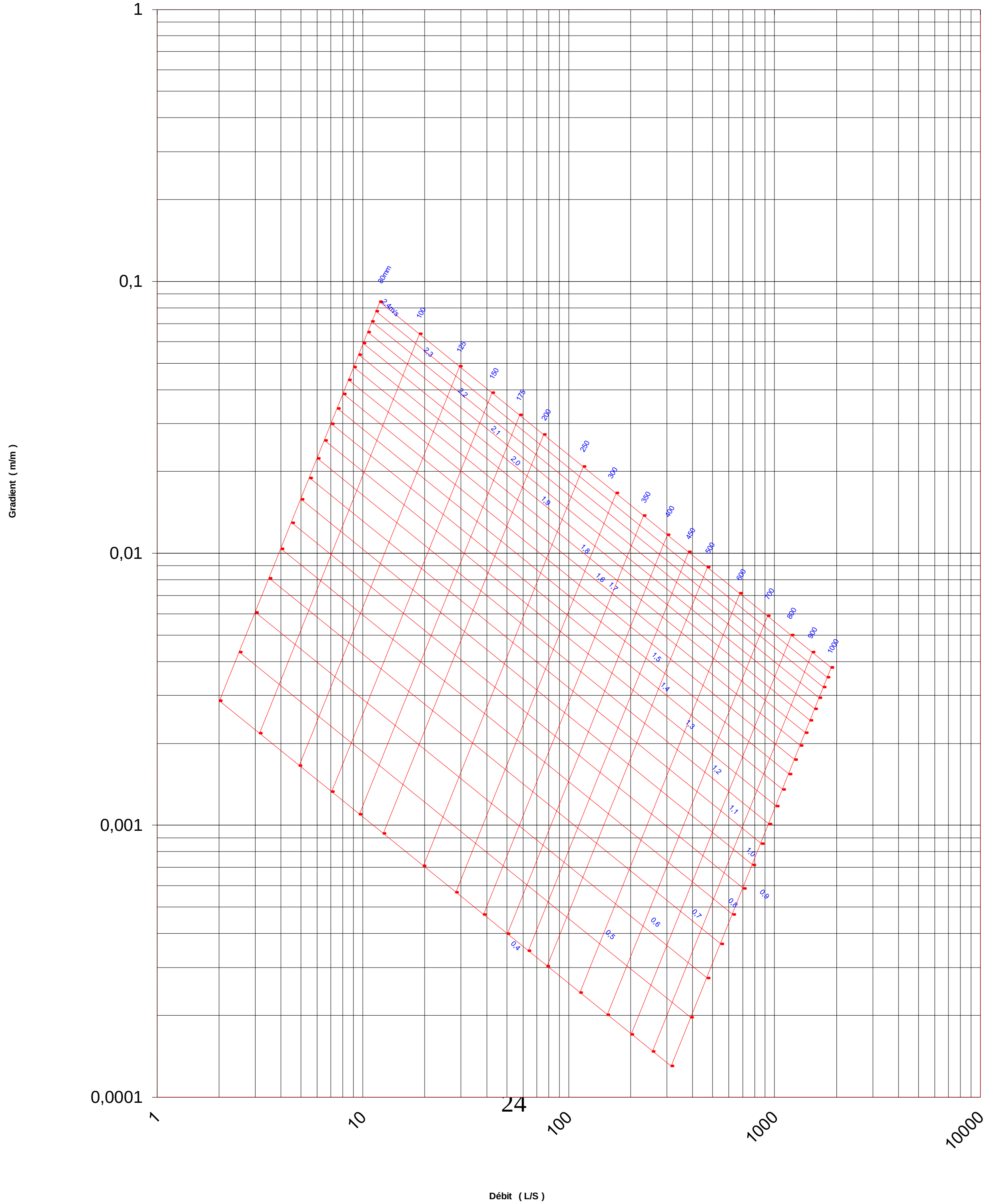
Graph load loss calculation by rubbing in the uplift pipes,K=2mm



Graph load loss calculation by rubbing in the uplift pipes,K=1mm



Graph load loss calculation by rubbing in the uplift pipes,K=0,1mm



NCLUSION

A bad load losses evaluation warsens directly the situation in water networks (insufficient pressure, flow reduction, the early deterioration of the electromechanical equipment, etc...) . To find a solution to this problem, a deep study and discussion are necessary. This team work allows to assemble the works concerning the topic of our study and to proceed to a discussion between different methodological approaches, hypotheses and results.

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