DETERMINING THE ENERGY INVOLVED IN THE INSTALLATION OF PEHD PIPES. APPLICATIONS OF DETERMINING THE ECONOMIC DIAMETER OF PRESSURE PIPES IN IRRIGATION SYSTEMS

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Abstract

The main purpose of the paper is the economic evaluation of the construction of pipeline networks under pressure, within irrigation systems. In this sense, the following stages were completed: (1) the technology for the execution of the pipeline network was established; (2) the phases related to the execution technology were established, respectively, grouped by categories of work, are as follows; (3) category of earthworks: mechanized excavation when making a trench related to the pipeline network; manual excavation when making a trench related to the pipeline network; mechanized filling when making the pipe network; (4) manual filling when making the pipeline network; mechanized compaction when making the pipe network; manual compaction when making the pipe network; making (manual filling) the sand bed; the mechanized spreading of the surplus earth resulting from the excavation; (5) category of construction and assembly works: preparation for joining pipes (tubes); joining by welding the pipeline (tubes); laying of pipes (tubes); (6) corresponding to the technological phases of the construction of the pipeline network, estimate items were allocated using WindevRO version 7.3 quotation preparation software, with the price catalog related to the semester preceding the preparation of this paper; (7) going through the above stages, the price per linear meter of pipeline executed in the field, equipped with PEHD, PE 100, PN 10 pipes and the range of diameters DN 90...DN630, was evaluated. By using these prices a mathematical model was established and the accuracy of determining the economic diameter for pressure pipe networks within irrigation systems has been improved.

Key words: execution technology, economic diameter, pipeline network

The main objective of the paper is to develop an algorithm for the economic evaluation of the execution works of pipeline networks under pressure, within irrigation systems.

The use of the costs devised in this way will allow us to establish an optimal and objective technical-economic-energy efficiency of the irrigation systems.

MATERIAL AND METHOD

In order to achieve the object proposed in this paper, we went through the following stages:

- establishing the pipeline network execution technology;
- establishing the phases related to the adopted execution technology;
- corresponding to these pipeline network execution phases, the quote items were allocated using the software for preparing quotes (Softeh Plus, 2023 - WindevRO V.7.3), with the related price catalog;
- going through the above stages, the price per linear meter of pipeline executed in the field, equipped with PEHD, PE 100, PN 10 pipes and the range of diameters DN 90...DN 630, was evaluated.

Next, detailing the stages presented above will allow us to solve the proposed objective.

Regarding the execution technology of the pipeline network, a mixed technology was adopted, respectively, mechanized supplemented with manual technology. Regarding the phases related to the execution technology, we have established work groups and related work categories, as follows:

- the group of mechanized and manual earthworks;
- group of construction and installation works.

Within the first group of works, we established the categories of works/technological phases of execution (NP 133, 2022), respectively:

- mechanized excavation when making a trench related to the pipeline network;
- mechanized compaction when making the pipeline network;
- mechanized filling when making the pipe network;

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- manual excavation when making a trench related to the pipeline network;
- manual filling when making the pipeline network;
- making (manual filling) the sand bed;
- the mechanized spreading of the surplus earth, resulting from the excavation

Within the group of construction and assembly works, we established the categories of works/technological phases of execution, respectively:preparation for joining pipes (tubes);joining by welding the pipeline (tubes); and laying of pipes (tubes).

With regard to the allocation of quotation items, using software for the preparation of quotations, for the financial evaluation of the technological phases of execution, the following stages were completed:

- we carefully analysed all the technological phases of execution that must be completed, presented above;
- we analysed the concrete conditions in which the technological phases must be carried out, according to the specialized technical legislation (NP 133, 2022, SR 4163-3, 1996);
- regarding the technological phases related to embankments - which are carried out at ground level and in its depth - indicated at current numbers 1, 2, 3 and up to 8 (*table 1)*, all these works are carried out in the conditions of light, non-cohesive soils (from the point of view of land category I and II), from a pedological aspect, they are similar to arable, loose land, land in general, suspended current agricultural/agrotechnical works, specific to the growing season (we considered the pipelines located with the upper generator at a depth of 0.90 m);
- corresponding to the technological phases and specialised technical restrictions (standards, technical regulations), we allocated, to all the technological phases of execution, the estimate items using specialised software (Softeh Plus, 2023; *table 1*).

We mention the fact that in column 3 of *table 1*, the suggestive name of the technological phase related to the estimate item in column 2 is inserted; in reality, the definition of the article is much broader, specifying all the concrete conditions for the realisation of the technological phase. In this sense, for example, *figure 3* shows the technological phase from current position 25, from *table 1* in detail.

When running the quotation software, simultaneously with the creation of the financial entity structure related to the works presented above, the list of recapitulation coefficients was established. *Figure 1* shows the coefficients in the default version. For the analysed case study, we departed from the default variant, with the addition of the recapitulation coefficients related to "Direct expenses" (10%) and, respectively, "Profit" (5%), to the value indicated in *figure 2*, with the adopted version.

RESULTS AND DISCUSSIONS

Going through all the stages presented above, in *table 2*, below, the costs are centralised - expressed in lei, euros and kWh - for one linear meter of pipe, equipped with PEHD, PE 100, PN 10 pipes and the range of diameters DN 90...DN 630, executed in the field.

The series of nominal diameters chosen, from the diameter of 90 mm to the nominal diameter of 630 mm, is in concordance with the level of the secondary infrastructure in our country; the nominal pressure of 10 bar is also optimal at the level of the infrastructure specified above.

We mention the fact that the price in lei, corresponds to the pricing catalog, where the price database related to the software is updated every six months.

The energy value (kWh) was obtained by converting the currency, leu, into electricity, respectively 1,004 lei/kWh, with a VAT of 19%; is the price of active energy, at the level of August 2024, which was applied to the supply of water for the irrigation of the secondary irrigation infrastructure (the irrigation systems of the Albița-Fălciu Complex for Hidroameliorative Development) from Vaslui county, an area administered at the macro level, by ANIF, in case, by the Territorial Branch of Vaslui Land Improvements.

Taking as a reference the price of electricity at the level of August 2024, the lei/euro exchange rate was adopted, from the end of the same month, namely 1euro = 4.9769 lei, 30.08.2024, BNR bank.

The centralised costs in *table 2* were applied within an original mathematical model to determine the optimal technical-economic diameter, D_{opt}, of a pipe in the network of an irrigation plot, which transports the Q_C flow.

To simplify the exposition, without affecting the generality of the results, we will consider a pipe section executed in the field, of unit length, and all related expenses will be expressed in the unit of electricity, kWh.

The performance criterion, considered in determining the diameter D_{opt}, consists in minimizing the amount of annual expenses G_{c_E}, (*equation 1*).

$$\min(G_{c\_E}) = \min(C_{ac} + C_E) \quad (1)$$

where:

C_{ac} are the expenses related to the amortization of the investment in the pipeline section, of diameter D_{opt}, and C_E the electricity consumed by the pressurization station to cover the load losses on said section, when transporting the QC flow.

Table1

The quoted items assigned to the technological phases of the execution of the pipeline network under pressure

No.	*Quoted items*	*The suggestive name of the technological phase of execution, related to the estimate of the item*
1	TSC03XB(93)	Mechanized pipe network excavation
2	TSA02E1(82)	Manual excavation of the pipe network
3	TSD02XB(93)	Mechanized filling of pipe network
4	TSD01XB(93)	Manual filling of the pipe network
5	TSD05XA(93)	Mechanized compaction at the pipe network
6	TSD04XC(93)	Manual compaction at the pipe network
7	ACF03A(99)	Manual sand filling (sand bed) at the pipe network
8	TSD03XA(93)	Mechanized spreading of the excavation surplus on the surface of the land
9	00601A03(02)	Tub PEHD PE 100, PN10, DN90, preparation for jointing and laying in the ground after jointing
10	00601A04(02)	Tub PEHD PE 100, PN10, DN110, preparation for jointing and laying in the ground after jointing
11	00601C01(02)	Tub PEHD PE 100, PN10, DN125, preparation for jointing and laying in the ground after jointing
12	00601C02(02)	Tub PEHD PE 100, PN10, DN140, preparation for jointing and laying in the ground after jointing
13	00601C03(02)	Tub PEHD PE 100, PN10, DN160, preparation for jointing and laying in the ground after jointing
14	00601C04(02)	Tub PEHD PE 100, PN10, DN180, preparation for jointing and laying in the ground after jointing
15	00601C05(02)	Tub PEHD PE 100, PN10, DN200, preparation for jointing and laying in the ground after jointing
16	00601C06(02)	Tub PEHD PE 100, PN10, DN225, preparation for jointing and laying in the ground after jointing
17	00601C07(02)	Tub PEHD PE 100, PN10, DN250, preparation for jointing and laying in the ground after jointing
18	00601C08(02)	Tub PEHD PE 100, PN10, DN280, preparation for jointing and laying in the ground after jointing
19	00601C09(02)	Tub PEHD PE 100, PN10, DN315, preparation for jointing and laying in the ground after jointing
20	00601C10(02)	Tub PEHD PE 100, PN10, DN355, preparation for jointing and laying in the ground after jointing
21	00601C11(02)	Tub PEHD PE 100, PN10, DN400, preparation for jointing and laying in the ground after jointing
22	00601C12(02)	Tub PEHD PE 100, PN10, DN450, preparation for jointing and laying in the ground after jointing
23	00601C13(02)	Tub PEHD PE 100, PN10, DN500, preparation for jointing and laying in the ground after jointing
24	00601C14(02)	Tub PEHD PE 100, PN10, DN560, preparation for jointing and laying in the ground after jointing
25	00601C15(02)	Tub PEHD PE 100, PN10, DN630, preparation for jointing and laying in the ground after jointing
26	00602D04(02)	Pipeline welding PEHD PE 100, PN 10, DN90
27	00602D05(02)	Pipeline welding PEHD PE 100, PN 10, DN110
28	00602D06(02)	Pipeline welding PEHD PE 100, PN 10, DN125
29	00602D07(02)	Pipeline welding PEHD PE 100, PN 10, DN140
30	00602D08(02)	Pipeline welding PEHD PE 100, PN 10, DN160
31	00602D09(02)	Pipeline welding PEHD PE 100, PN 10, DN180
32	00602D10(02)	Pipeline welding PEHD PE 100, PN 10, DN200
33	00602D11(02)	Pipeline welding PEHD PE 100, PN 10, DN225
34	00602D12(02)	Pipeline welding PEHD PE 100, PN 10, DN250
35	00602D13(02)	Pipeline welding PEHD PE 100, PN 10, DN280
36	00602D14(02)	Pipeline welding PEHD PE 100, PN 10, DN315
37	00602D15(02)	Pipeline welding PEHD PE 100, PN 10, DN355
38	00602D16(02)	Pipeline welding PEHD PE 100, PN 10, DN400
39	00602D17(02)	Pipeline welding PEHD PE 100, PN 10, DN450
40	00602D18(02)	Pipeline welding PEHD PE 100, PN 10, DN500
41	00602D19(02)	Pipeline welding PEHD PE 100, PN 10, DN560
42	00602D20(02)	Pipeline welding PEHD PE 100, PN 10, DN630

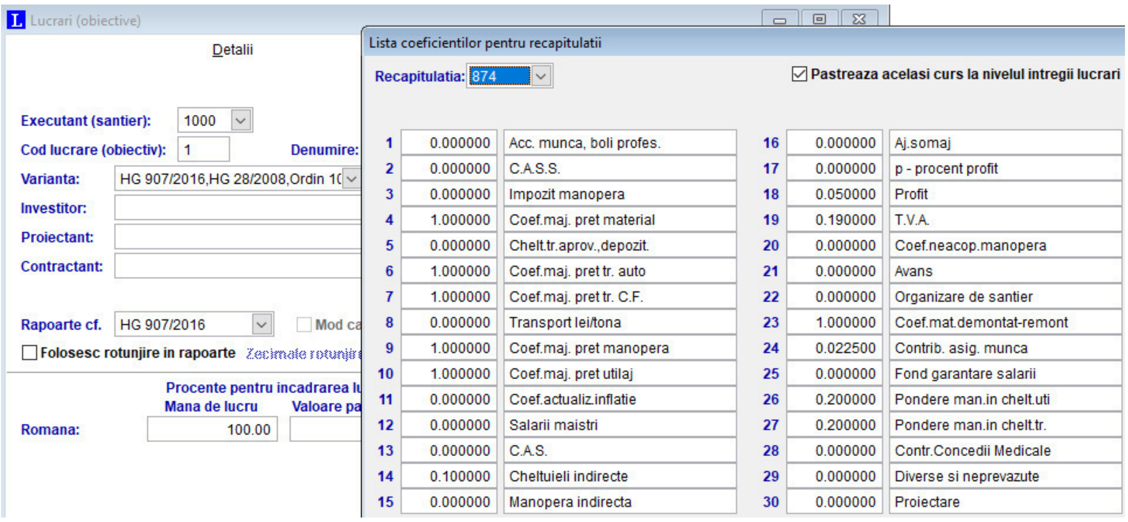

Figure 1 **List of calculated software recapitulation coefficients, default version**

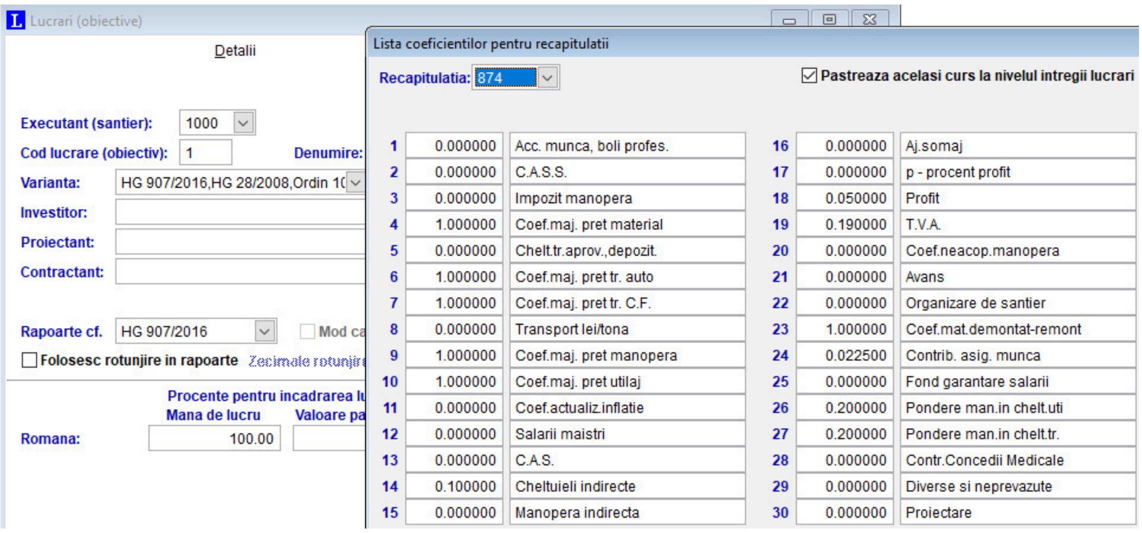

Figure 2 **List of calculated software recapitulation coefficients, adopted version**

Articolul 00601C15 02 Rețeta pentru 1m
Pregătirea pentru îmbinarea tuburilor din PEHD cu D = 630 mm în bare L = 12 m și poziția în pământ după îmbinare

Cod resursa	Tip resursa / Denumire resursa	U/M	Cantitate	Pret	Valoare
1	2		3	4	5
2901118	Material BILE, MANELE RASINOASE D = 15-18 CM	M CUB	0.003600	1152.37	4.15
8815165	Material BANDA AVERTIZARE GAZ 15,0CM X 0,09MM Componenta listei anexa LA006A2	M	1.100000	1.10	1.21
8815544	Material TUB PEHD APA PE100 SDR17 PN10 D.630 X37,4 MM Componenta listei anexa LA006A1	M	1.015000	1690.02	1715.37
0019900	Manopera MUNCITOR DESERV.CTII MONTJ.	ORE	0.330000	30.42	10.04
0025000	Manopera MONTATOR CONDUCTE	ORE	0.680000	35.10	23.87
1935	Utilaj MACARA PE PNEURI	ORE	0.033000	294.00	9.70
Greutate	0.000	Total ore	1.01	Total	1764.34

Figure 3 **Detailed execution technological phase, related to estimate item 00601C15**

C_{ac} expenses are assessed with the following (*equation 2*):

$$C_{ac} = \frac{p_{Ad} + (1 - p_{Ad})(1 + N_{l-r} r_I)}{T_a} e_C \qquad (2)$$

where:
r_I = bank interest rate;
N_{l_r}= number of years for bank loan repayment;
p_{Ad} = advance amount for the investment;
e_C = energy embedded in the pipe section;
T_a = the amortization period of the investment.

E_C expenses are evaluated with the following (*equation 3*):

$$C_E = \frac{8}{\pi^2} \frac{T_0}{\eta_P \cdot \eta_m \cdot \eta_{TS}} \frac{\lambda Q_C^3}{D_{opt}^5} \qquad (3)$$

where:
T_0 = number of operating hours of the pumping units within a year;
η_P = pump efficiency;
η_m = efficiency of the electric motor;
η_{TS} = the global performance of electromotor-pump transmission systems;
λ = the Darcy Weissbach resistance coefficient, calculated with the Colebrook White formula.

Next, the above mathematical model was customized for the following numerical data:
r_I = 0.07, N_{l_r} =10 years, p_{Ad} =0.25, e_C = according to Table 2, columns 1, 2 and 5, T_a =25 years;
T_0 = 1798 (hours/year); η_P =0,87, η_m =0,954; η_{TS} =1 (direct coupling).

The evaluation of the resistance coefficient λ, we considered the kinematic viscosity υ =$1.006 \cdot 10^{-6}$ m^2/s and the equivalent absolute roughness k=$7.0 \cdot 10^{-6}$ m.

The results, obtained with MATLAB, are presented synthetically in (*figure 4*) and (*figure 5*).

Table 2

The cost of running pressure pipes in irrigation systems

No.	Pipeline specifications	lei/ml, without VAT	euro/ml without VAT	kWh/ml
1	Pressure pipe network made of tubing din PEHD PE 100, PN 10, DN 90	217.73	43.75	258.07
2	Pressure pipe network made of tubing din PEHD PE 100, PN 10, DN 110	250.64	50.36	297.07
3	Pressure pipe network made of tubing din PEHD PE 100, PN 10, DN 125	241.65	48.55	286.42
4	Pressure pipe network made of tubing din PEHD PE 100, PN 10, DN 140	271.72	54.60	322.06
5	Pressure pipe network made of tubing din PEHD PE 100, PN 10, DN 160	309.60	62.21	366.96
6	Pressure pipe network made of tubing din PEHD PE 100, PN 10, DN 180	357.95	71.92	424.26
7	Pressure pipe network made of tubing din PEHD PE 100, PN 10, DN 200	402.71	80.91	477.31
8	Pressure pipe network made of tubing din PEHD PE 100, PN 10, DN 225	469.61	94.36	556.61
9	Pressure pipe network made of tubing din PEHD PE 100, PN 10, DN 250	541.99	108.90	642.39
10	Pressure pipe network made of tubing din PEHD PE 100, PN 10, DN 280	711.89	143.04	843.77
11	Pressure pipe network made of tubing din PEHD PE 100, PN 10, DN 315	835.63	167.90	990.43
12	Pressure pipe network made of tubing din PEHD PE 100, PN 10, DN 355	999.43	200.81	1184.59
13	Pressure pipe network made of tubing din PEHD PE 100, PN 10, DN 400	1240.54	249.26	1470.37
14	Pressure pipe network made of tubing din PEHD PE 100, PN 10, DN 450	1425.12	286.35	1689.14
15	Pressure pipe network made of tubing din PEHD PE 100, PN 10, DN 500	1716.51	344.90	2034.51
16	Pressure pipe network made of tubing din PEHD PE 100, PN 10, DN 560	2091.49	420.24	2478.96
17	Pressure pipe network made of tubing din PEHD PE 100, PN 10, DN 630	2558.42	514.06	3032.39

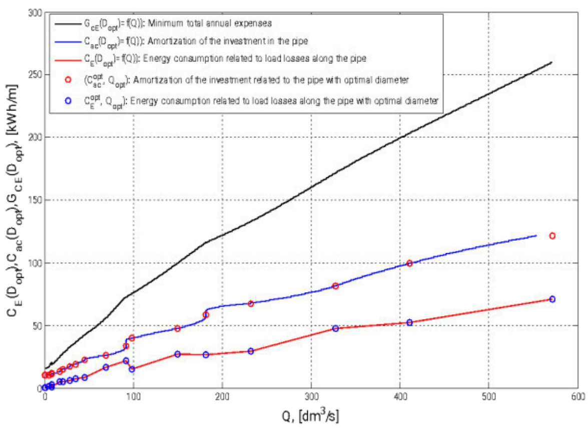

Figure 4 **Variance of optimal annual expenditure (related to minimum total expenditure, G_{CE}), by debit**

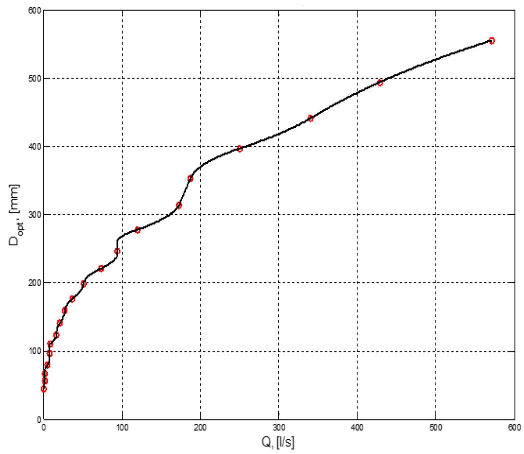

Figure 5 **Variance of optimal diameter, D_{opt}, as a function of flow rate**

CONCLUSIONS AND RECOMMENDATIONS

The obtained results, respectively, the energy value involved in the execution of pipe networks made of tubes/pipes with the range of diameters specified in *table 2*, will/can be used in an already established mathematical model, improving the precision of determining the economic diameter for pressure pipe networks within irrigation systems.

The optimal economic design of pipeline networks under pressure, related to irrigation systems, based on the energy quantification established by this paper, will allow the successful development of the economic-energy efficiency analysis of total investments in new irrigation systems. In the calculation of economic-energy efficiency, it is possible to energetically quantify all the investments made in the irrigation system, with its effect translating into an increase in agricultural production obtained by farmers, agricultural production that is easy to quantify energetically (Logigan I., 2003*;* Logigan I., 2005); thus, in the end, we obtain the economic-energetic effect of the investment in an irrigation system, objectively, eliminating the controversies that appear when analysing the classic economic efficiency, financially evaluated (lei/euro).

We mention that in the work (Pricop A. *et al*, 2000) when determining the optimal diameter for pipe sections of water distribution networks, the energy embedded in the pipe section, *ec*, consists only of the expenses related to the amortisation of the cost of purchasing the pipes, but not those relating to the actual execution of the network.

REFERENCES

Logigan I., 2003 - *Contribuții privind estimarea eficienței economico-energetice a amenajărilor complexe antierzionale*, U. T. “Gh. Asachi” Iași, Teză de doctorat.

Logigan I., 2005 - *Eficiența economico-energetică a amenajărilor de protecție antierzională a terenurilor*, Edtitura Performantica Iași, ISBN 973-730-110-2.

Pricop A, Leu D., Logigan I., Marcoie N., 2000 - *Contribuţii la dimensionarea optimă în MATLAB a reţelelor de distribuţie a apei cu scenarii multiple de funcţionare* – Buletinul Institutului Politehnic Iaşi, Tomul XLVI (L), Fasc. 1-4/2000, Iaşi.

NP 133, 2022 - *Normativ privind proiectarea, execuția și exploatarea sistemelor de alimentare cu apă și canalizare a localităților. Vol. I – Sisteme de alimentare cu apă*, Normativ de proiectare.

SR 4163-3, 1996 - *Alimentări cu apă. Rețele de distribuție. Prescripții de execuție și exploatare*, Legislație de proiectare.

Softeh Plus, 2023 - *WindevRO V.7.*3, Software întocmire devize.