RESEARCHES ON THE MODERNIZATION OF THE CONDUCT NETWORK FROM OLD PRESSURE IRRIGATION SYSTEMS

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Abstract

The paper presents a series of concepts regarding the rehabilitation and modernization of the pipeline network in irrigation systems with sprinkling. Old spray irrigation systems in operation for about 30-40 years show wear and aging phenomena of structural components (pipes, pits, hydrants). Research on about eight sprinkler irrigation plot with pipeline networks in various exploitation concepts highlighted the complexity of the rehabilitation and upgrading process. Rehabilitation of the pipeline network is based on the type of irrigation equipment with which the irrigation plot is fitted. In the case of plots equipped with monofilament pumping stations the tertiary distribution pipeline is rehabilitated at the level of the current technique and automation equipment is introduced. The rehabilitation process must be carried out in successive stages and using modern materials and technologies of endowment and execution. Case studies developed for sprinkler irrigation plots located in Moldova are customized on the modernization directions adopted by the beneficiary: pivot spraying equipment, longitudinal displacement equipment, fixed watering equipment, etc.

Key words: pressure pipes, hydrants, dormitories, design, modernization rehabilitation

At the level of 1989, Romania had a series of irrigation systems with a technical level corresponding to the existing technologies and production materials at national and international level. Irrigation systems have contributed to the conditions of development of agricultural and horticultural crops in the climate conditions specific to Romania. Prior to 1989, a wide range of watering methods were used: watering by sprinkling, furrowing, bivalent watering, dripping, etc. Irrigation systems were formed by irrigation plotting, which was the basic unit of the system (Blidaru *et al*, 1981, Cazacu *et al*, 1982).

After 1990, most of the irrigation systems were dismantled by changing ownership of the land and by governmental decisions. Currently there is only a small number of irrigation systems built before 1989, and all are in a private system. Irrigation systems in operation show degradation processes to the construction structure and to installations serving the exploitation process. The watering method used predominantly is watering by spraying (Luca *et al*, 2016).

Irrigation is currently being applied on very small areas and uses the infrastructure built before 1990 for large irrigation systems. Small irrigation systems (mostly at irrigation plot level) with aspiration are most used in the current state. Most of these systems were built in 1970-1985.

Irrigation systems built before 1990 were water-based, pumping stations that lifted water at various elevations, transport channels, pressure or bivalent watering stations, protection and control facilities, and so on. (Blidaru *et al*, 1981, Cismaru, 2004).

Irrigation plots for sprinkler irrigation currently in operation show degradation processes in the pipeline. The pipeline network was executed between 1975 and 1982 and has an outdated service life, showing a large number of damage per year. The pipeline network has large water losses and low operating efficiency. Also, the pipeline network no longer meets the current technical requirements required by the use of modern watering equipment (Luca M., 2017).

The objective of the paper is to present a way of rehabilitation of the pipeline network under the pressure of old irrigation plots with sprinkling.

MATERIAL AND METHOD

The study and research material is represented by irrigation systems, ie irrigation plots located in the counties of Iasi and Vaslui. Irrigation systems are fed from the Prut River and are located in the meadow area on the first and second terraces (*figure 1*). The water take-off from the Prut River is made with base pumping stations (SPB) and the water is raised on terraces with pumping stations (SRP), which feed a series of

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transport and distribution channels or pipes (Luca, 2012, Luca, 2015).

Irrigation plots are fed from channels or pipelines and are equipped with SPP or single stranded pumping stations (SPPM). Irrigation plots have a pipeline network made about 40-50 years ago.

The study and research areas were as follows:
- The area is located in the system in South Soloneţ, Iaşi County, on a terrace.
- Zone II located in the Albiţa Fălciu Complex Irrigation and Drainage Complex, on a plain relief (dense enclosure).

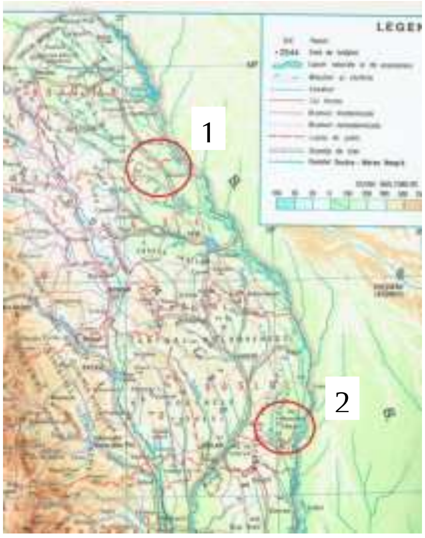

Figure 1 **Study and Research Areas: 1 - Southern Solonet irrigation system; 2 - Complex Irrigation and Drainage Design Albiţa Fălciu**

For each irrigation system and irrigation plot considered in the analysis a technical documentation was carried out. For a series of irrigation plotting, technical expertise has also been carried out. Through documentation, the state of structural components was analysed on the basis of known and accessible data. The data provided by the technical expertise allowed the analysis of the current state of construction of the irrigation plotters in operation after a period of 40-50 years. The irrigation plot pipeline networks have been analysed based on data collected from the technical expertise developed over the last period of time.

The research method is used to perform technical expertise for land improvement objectives, and in particular for irrigation plots with pumping stations.

Field research has taken photos and videos. For some irrigation plots, updated topographical plans of irrigation systems in use were used. The data processing followed the methodology used in the technical and scientific analyzes developed for irrigation systems with channel and pipeline networks.

RESULTS AND DISCUSSIONS

Irrigation plots with sprinkling and mixed watering (spraying + furrows) were made in the 1970s and 1980s based on well-designed projects (Project No. 4824-R 1987). Irrigation plots in Romania were designed to water an area of 500-2500 ha. The pipeline network is fed by a SPP or by a number of monofilament pumping stations (SPPM). The pump pumping is supplied from a duct or duct belonging to the irrigation system. The irrigation plot is integrated into the irrigation system infrastructure, or can be individually designed for small areas.

The following requirements are considered when designing the sprinkler irrigation plot (Cazacu *et al*, 1982):
- constructive and functional parameters of watering equipment;
- the characteristics of the pipeline network to ensure the flows and pressures required by the number of watering equipment in operation,
- functional parameters of the pressure vessel.

Some of the irrigation plots were constructed with a single pipeline network or with a mixed pipe network, as follows:

a. Plane with a high pressure pipeline network (P = 7.0 - 8.0 bar) powered by a pressure lift pump (SPP).

b. Plot with a combined high pressure pipeline network for bivalent watering (sprinkling and furrowing) powered by a pumping station (SPP).

The pipe network for variant "a" is of a branched type and is calculated at the flows required by the watering equipment. The pipeline network is fed by a pumping and pressure station (SPP) located centrally or laterally to the plot (Project No. 4824-R 1987).

The "b" duct network is branched and consists of two rows of main and secondary pipelines for water transport to watering equipment. The pipeline network is powered by a pump and pressure boosting station (SPP) equipped with two pump sets with differential flow and pressure. Welding pumps have high flow rates and medium pressures (P = 3.5-4.5 bar), and those for sprinkling have lower flows and high pressures (P = 7.0 - 8.0 bar).

Irrigation plots with sprinkler irrigation and bivalent watering have been made in a monofilament scheme, respectively, with monofilament pumping stations fed from channels. Plots of this type were made more in the plain area and the dilapidated enclosure (Cazacu *et al*, 1982).

Bivalent irrigation plots (furrows and aspersion) were transformed after 1990 into sprinkler screens.

In most irrigation plots with sprinkling and bivalent watering, the hydromechanical installations of the pumping stations (SPP and SPM) were rehabilitated in the first or part stage. The pipeline network was not rehabilitated at this stage (Luca, 2012, Luca, 2015).

The pipeline network of irrigation plots in operation has a long service life. The absence of maintenance and repair work and overheated lifetime have led to the degradation of structural components of pipelines, hydrotechnical structures on the grid and hydraulic installations in dormitories. In the same situation there are the irrigation channels, which feed the monofilament pumping stations from irrigation plots with sprinkling (Luca, 2016).

The analysis carried out in the Irrigation Plot SPP1b Soloneţ revealed that the pipeline network is in branched form (*figure 3*) and has the following components (Luca, 2012):

- the main pipeline CP2b in length of 8955 m, made of PREMO tubes (Dn 800, Dn 600 and Dn 400) and powered by SPP1b;
- four secondary pipes (CS2, CS3, CS4 and CS5) with a total length of 8565 m, made of PREMO Dn 400, AZBO Dn (350-200) tubes and fed by CP2b;
- 38 tertiary irrigation pipelines (irrigation aerials, A30b ... A67b) with a total length of 23.128 m, made of AZBO, PVC, steel (in high pressure areas) with diameters 250 - 100 mm and fed from CS;
- hydrants for powering manually moved watering systems (mechanized move, later); the watering line is equipped with 17 sprinklers; for wet watering were used mobile watering sets type EUBA - 150;
- grid constructions: junction shafts, ventilation shafts (*figure 2*), massive anchor drainage hoods, sub-crossings etc.

The pipeline network of the SPP1b irrigation plots was commissioned in 1981.

Figure 2 **Degradation state of buildings and installations on the pipeline network of the plot Irrigation SPP1b** (Luca, 2015)

The structural degradation of the pipeline led to the occurrence of large water losses, the progressive increase in the number of damages and the increase of the energy consumption (Cismaru, 2004, Luca, 2012, Luca, 2016).

Increased operating costs and low yields of sprinkler irrigation plots required the rehabilitation of the pipeline network.

The rehabilitation of the pipeline network of the irrigation plot is based on a technical expertise and a technical project approved by a project verifier on the field of land improvement. The technical design may provide for the partial or total change of piping that forms the pipeline. The hydraulic installation in the dorms needs to be completely changed, as the service life is exceeded.

The technical design should take into account the current cropping plan in the irrigation plot to determine the irrigation norm (*M*), watering norm (*m*) and watering hydromodule (q_u).

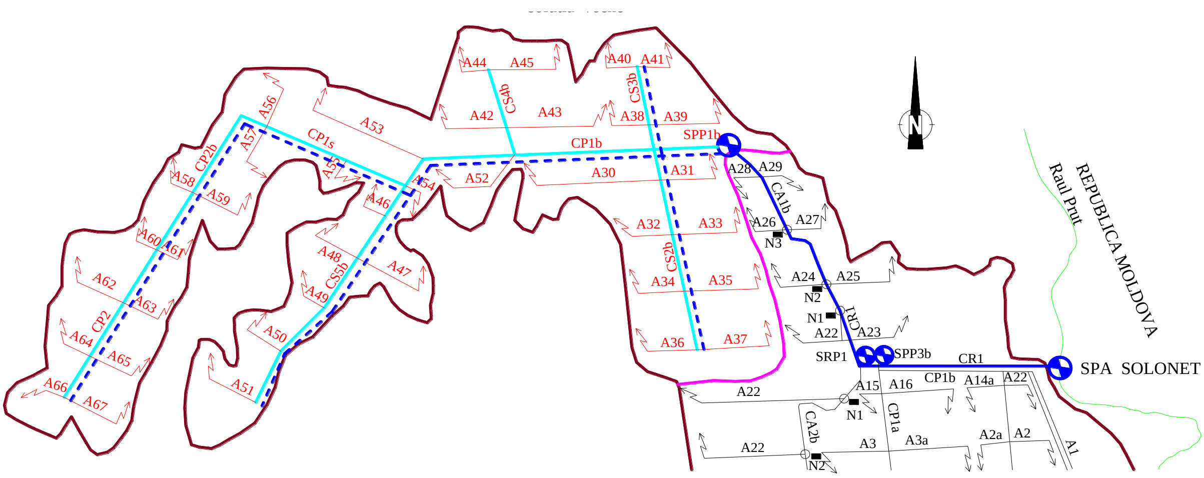

Figure 3 **Initial plot of irrigation plot SPP1b South Solonet: continuous line - main / secondary high pressure pipelines; interrupted line - main / secondary medium pressure pipes** (Luca, 2015)

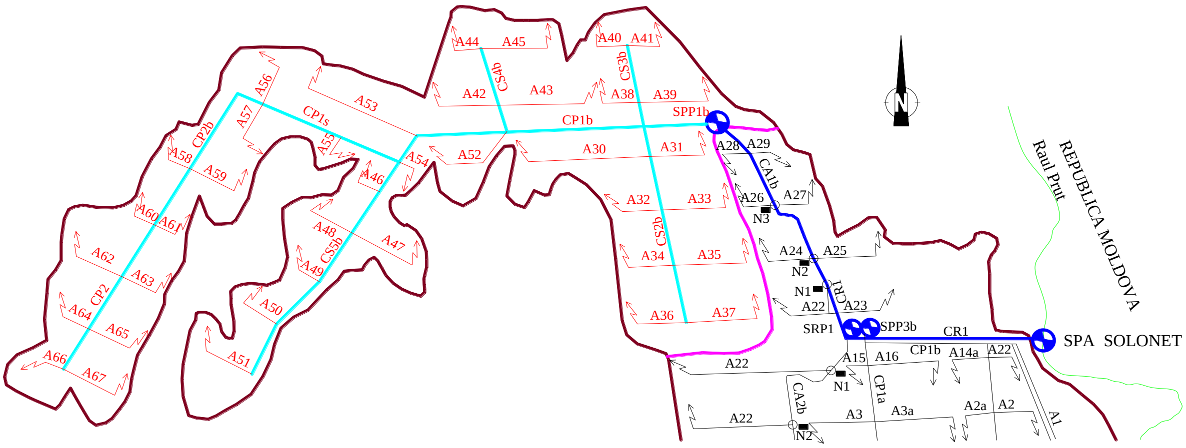

Figure 4 **The new piping network layout at the SPP1b South Solonet irrigation plot**

The watering hydromodule is determined by the relationship (Cazacu *et al*, 1982, Stancescu *et al*, 1985):

(1) $$q_u = \frac{1000\, m}{T\, t}$$

The relationship of the irrigation plot sizing flow calculation is as follows:

(2) $$Q_{PI} = S q_{u,pond} \frac{1}{\eta_c} \frac{1}{\eta_r} \frac{24}{t}$$

care se verifică cu relaţia

which is verified with the relationship

(3) $$Q_v = \sum Q_{av} \frac{1}{\eta_r}$$

In relations (1), (2) and (3), the notations used have the meaning: q_u is the watering hydromodule; q_{up} - medium weighted watering hydromodulus; m - watering norm; T - the number of days considered in the peak month; t - watering time per day; S - wetted area; η_c - watering efficiency in the field; η_r - network yield downstream of the pumping station; t - actual hours of operation of the watering equipment (in ec. 2); Q_v - Verification Flow Q_{av} - the sum of flows downstream of the calculated item.

Parameters of the irrigation regime considered when designing the SPP1b Soloneţ Nord irrigation plot are shown in Table 1.

Table 1

Parameters of irrigation regime at Plot SPP 1b

p **(%)**	***M*** **(m³/ha)**	***m*** **(m³/ha)**
50	2600	1200
80	3700	1350
p - calculation assurance		

The maximum watering hydromodulus used for the initial design of the irrigation plot resulted in corn crops and was 0.53 *l*/s x ha. The weighted average net hydromodule used in the design was 0.50 *l*/s x ha (Luca, 2012).

The constructive modification of a pipe section or of a main and secondary pipeline within the pipeline requires a new dimension of the grid (*figure 4*). Changing the type of watering system requires a new dimension of the hydrants and pipelines within the network. The watering equipment used in the irrigation plot is of the "pivot" type (*figure* 5), which requires a complete dimensioning of the pipeline network, considering the modification of the parameters of the hydrants, changing the flows and pressures in the nodes. The new layout scheme will be designed for a high-pressure pipeline network to ensure the operation of modern sprinkler systems.

Figure 5 **Pivot type watering system in the "SPP1b South Soloneţ" pressure irrigation plot** (Luca, 2015)

In 2019, the technical documentation for the rehabilitation of a section of the main pipeline CP2b on a 970 m length, supplied by the first pumping stage (high pressure) was elaborated. The rehabilitated section is located between the SPP1b pumping station and the CS2b and CS3b secondary connection junction. The pipeline section was made of PREMO Dn 800 tubes, and by rehabilitation will be made of PEHD Dn 800, Pn 10 pipe. Changing the material over an important length of pipe changes the hydraulic characteristic of the pipe network and implicitly parameters of the operating point of pumping station and pressurization (Q_F, H_F).

The hydraulic feature of the pipeline network on the most geodetically and hydraulically unpleasant route is determined with the relation:

$$(4) \quad H_c = H_g + \Sigma M_i \, Q^2$$

where H_c is the hydraulic load of the pipe network; H_g - geodetic height; ΣM_i - the sum of the resistance modules; Q - feed rate.

Parameters of the pumping station and pressure setting (Q_F, H_F) are determined by solving the system of equations:

$$(5) \quad \begin{aligned} H_c &= H_g + MQ^2 \\ H_p &= f_1(Q) \\ \eta_p &= f_2(Q) \\ N_p &= f_3(Q) \\ NPSH_p &= f_4(Q) \end{aligned}$$

where H_p is the pumping height; $f_1(Q)$ - load characteristic of the pumping station; $f_2(Q)$ - pumping station efficiency characteristic; $f_3(Q)$ - pumping station power characteristic; $f_4(Q)$ - cavitations characteristic of the pumping station.

The absence of total rehabilitation of the pipeline network leads to increased water losses on the old pipeline sections, which have an overheated exploitation period. The absence of rehabilitation of the pipes on the pipeline network, construction and hydraulic installations leads to an increase in the number of damages and consequently the loss of water.

A case study has been prepared for a sprinkler irrigation plot located in "Albiţa - Fălciu Complex Planting" Vaslui County. The irrigation plot “16 Berezeni” is located at the southern boundary of Satu Nou - Berezeni village, Berezeni commune, Vaslui County.

The total area irrigated within the plot is 986 ha. The irrigation system was designed by I.S.P.I.F. Bucharest in 1977 and was executed between 1977 and 1980.

The analysis carried out at "Plot 16 Berezeni" from the Albiţa - Fălciu Complex Irrigation and Drainage System (*figure 6*) revealed the totally unsatisfactory state of the constructive structure of the pipeline network under pressure (Luca M., 2015).

Figure 6 **Layout scheme of the of the pressure irrigation plot „Plot 16 Berezeni”** (Luca, 2015)

The large number of damages required partial rehabilitation of some pipe sections. The damage was also intensified by the failure of the hydraulic shock protection system. Pipes made from asbestos have been degraded by the hydraulic shock produced during the exploitation process (*figure 7*) (Luca, 2015).

Figure 7 **Condition of degradation of asbestos pipes in the structure of the pipeline network of "Berezeni Plot 16"** (Luca, 2015)

The pumping station of the irrigation plot „16 Berezeni” was partially rehabilitated at the level of the hydro-mechanical equipment in the last period of time. The pipeline network consists of the following components (Luca, 2015):

- main pipeline (CP1) made of PREMO Dn 800 to 400, Pn 10 tubes and Dn 350, Pn 10 asbestos, 2772 m long;
- tertiary pipes (irrigation antennas, 12 pieces) in total length of 21.248 m made of asbestos-cement tubes with Dn 350 ... 125, Pn 10 and connected to CP1; Dn 100 type normal and drainage hydrants are placed on the pipes;
- network construction: derivation dams, drainage and ventilation shafts, massive anchorages, etc.

In order to limit the number of damages on the main pipeline, a rehabilitation project for a 1770 m long section was prepared, where PREMO pipes with PRHD pipe were replaced. Also rehabilitated sections from the tertiary pipes in 3935 m length of asbestos pipe, which was replaced with PEHD pipe (*figure 8*).

Figure 8 **Rehabilitation of the ventilation chimney on the main pipe CP1 in "Berezeni Plot 16"** (Luca, 2015)

The problem of water losses in pipelines under pressure (6.0 to 8.0 bars) in the irrigation plot must be considered in the rehabilitation process. Water losses influence the efficiency of the pipeline network and, implicitly, the yield of the irrigation plot.

The efficiency of the pipeline network for the current exploitation case can be determined with the relationship (Stancescu et al, 1985):

$$\eta_c = \frac{\alpha * Q_{inst} * T_1 - \sum p_I * T}{\alpha * Q_{inst} * T_1} * 100 \ [\%] \qquad (6)$$

where: α is the ratio between the average daily flow rate and the flow rate installed at the SPP; Q_{inst} - installed SPP debit; Σp*i* - sum of the losses during the irrigation period, determined as a percentage of the total volume of pumped water; T_i - number of days of operation of SPP; T - the duration of the irrigation campaign in which the network was filled with water.

The efficiency of the pipeline network is not currently assessed by the irrigation plots.

The rehabilitation and upgrading of the pipeline network of the irrigation plots has to be done by redesigning the pipeline network by adopting a new concept of a layout scheme that considers the functional parameters of the modern watering installations.

CONCLUSIONS

1. Irrigation plots with sprinkling are the most often rehabilitated and upgraded components of the old irrigation systems that are still in operation in Romania.

2. The irrigation plot pipeline network must be rehabilitated in view of exceeding the operating life of most components (pipelines, chimneys, hydraulic installations, etc.) and large water losses occurring in the exploitation process.

3. The use of modern sprinkler systems in irrigation plotting requires the adoption of a new concept of pipeline network and the redimensioning of pipelines according to new flow and pressure requirements in the network nodes.

4. The rehabilitation of the pipeline network of the irrigation plots must be carried out in a complex way at the level of the current technique with the introduction of the monitoring and automation system of the exploitation process.

5. The design of the new pipeline network of the irrigation plot must be correlated with the characteristics of the pumping station and the pressure relief station (operating point parameters) to obtain the optimal flow and pressure when operating the operation process.

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