CONSIDERATIONS ON THE EXPERTISE OF PUMPING PLANTS FROM IRRIGATION SYSTEMS

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Abstract

The paper presented a series of concepts on the technical expertise of irrigation pumping stations. Sprinkling irrigation screens in operation show significant wear and aging phenomena. Any project for the rehabilitation and upgrading of a pumping station is based on technical expertise. It critically analyses the design, construction and operation of structural components and installations serving a pumping station. The technical expertise consists of four components: 1 - Critical analysis of the data on the achievement of the objective; 2 - field research and research on the behaviour of the objective during the exploitation period; 3 - complementary studies and research to define the response situations of the objective to the action of internal and external factors; 4 - the conclusions of the expertise and the directions of rehabilitation and modernization. The expertise for a sprinkler irrigation plot equipped with a pumping and pressure plant (considered a case study) highlighted the complexity of the rehabilitation and modernization process. The rehabilitation process must be carried out in successive stages and by using modern equipment and technologies.

Key words: design, hydraulic system, modernization, pumping aggregate

In Romania, during 1965 and 1989, a number of irrigation systems with a technical level corresponding to the technologies and execution materials available during that economic development period were executed. Irrigation systems have been fully operational, have ensured plant development conditions in Romania's specific climate and have covered the soil moisture deficit. The watering methods used are: bed irrigation, sprinkling irrigation, bivalent irrigation and drip irrigation. The base unit in the irrigation system operation was the „irrigation plot" (Blidaru V., *et al* 1981). Most of the irrigation systems were annulled after 1990 and only a small number are now in operation. Current operational irrigation systems show constructive and functional degradation processes. The watering method used predominantly at present stage is sprinkling irrigation (Luca M. 2016).

At present stage, the irrigation is applied for much smaller surfaces and uses infrastructure build before 1990. Small irrigation systems with sprinkling watering are used the most at present state. Most of these were carried out during 1967-1985.

The rehabilitation and modernisation of pumping and pressure plants (SPP) is done differentially on the structural and functional components: the constructive structure, the hydromechanical technological line, the hydraulic shock protection installation, the energy installation, the operational process monitoring and automation installation. The rehabilitation project is done based on a technical expertise carried out by an authorised expert in the field. The technical expertise carried out for multiple irrigation plots supplied with pumping plants highlighted the complexity of the rehabilitation and modernisation process (Luca M., 2015).

MATERIAL AND METHOD

The study and research material consists of a number of irrigation systems, respectively irrigation plots located in Iaşi, Vaslui and Brăila counties. The irrigation plots are equipped with pressurising pumping plants (SPP code) or with monofilament pumping plants (SPPM code). The irrigation plots are integrated into the infrastructure of irrigation systems built about 50 years ago. The location of the irrigation plots analysed was the following (*figure 1*):

- in the hill area, Soloneţ Nord, Iaşi County SPP1b plot (Luca Al., et al. 2016);
- in the plain area, in an impounded area, Berezeni Plot 16 and Berezeni Plot 17 from the Albiţa Fălciu Complex Irrigation and Drainage Facility (Luca M., 2015);
- in the plain area, in an impounded area, Vaslui County Doniceasa Fălciu Plot 7, Albiţa Fălciu

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Complex Irrigation and Drainage Facility (Luca M., 2016);

- in an island area, Brăila County, Great Brăila Island - Plot 42 (Luca M., 2015).

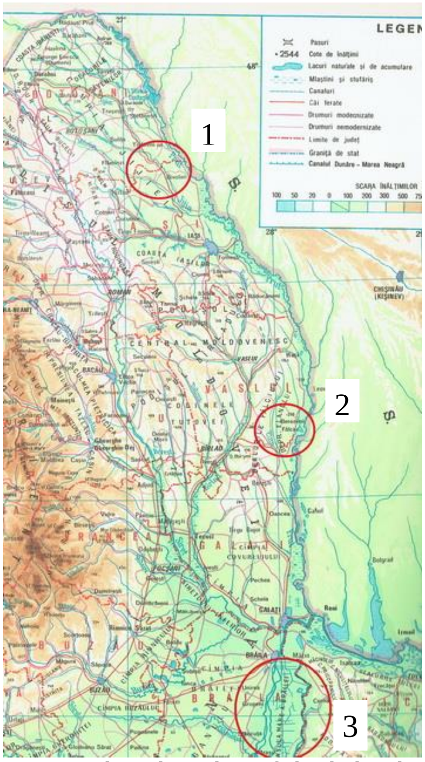

Figure 1 **Expertises location of the irrigation plot: 1- SPP1b North Solonet Plot; 2 – SPP 16 Berezeni Plot and SPPM 7 Doniceasa Fălciu Plot; 3 – SPPM 42 “Insula Mare a Brăilei”**

For each irrigation plot a technical expertise was carried out. It analysed the current constructive state of the pumping plant and pipe network, after 40 – 50 years of operational period. Also, the technical expertise analysed the current state of the constructions, installations and equipment which comprise the pumping plant. The technical expertises were carried out according to the current rules established for land reclamation objectives.

The research method is the one used during the technical expertise for land reclamation objectives and, in particular for irrigation plots with pumping plants. Each pumping plant is investigated on the ground on structural and specific installations components.

The data processing followed the methodology used in the technical expertise carried out for land reclamation pumping plants.

RESULTS AND DISCUSSIONS

Large surface irrigation systems have a number of structural components which ensure water catchment, its transportation and field distribution and the irrigation plots water supply. The water catchment is done with free level water inlets or with base pumping plants (SPB). The water transport is done gravitationally and by pumping using boosting stations (SRP). All of these make the land reclamation irrigation system infrastructure. Plant water distribution is done through irrigation plots (Blidaru V., et. al, 1981).

The sprinkling irrigation plot from irrigation systems in Romania was designed for watering an 800 – 2000 ha surface. It consisted of a pressurised pipe network supplied by a pumping plant. The pumping plant was supplied from a channel or a pipe. The irrigation plot is integrated into the irrigation system infrastructure or it can be individually designed for small surfaces.

The irrigation plot was designed in two pumping plant equipment alternatives:

a – irrigation plot equipped with a pumping plant for lifting pressure (SPP code);

b - irrigation plot with monofilament pumping plants (SPPM code, the plant supplies a single irrigation water distribution pipe).

In the first case, SPP supplies a pipe network designed for high pressures (7.0 – 8.0 bars). In the second case, the SPPM monofilament pumping plants are located on the supply channel and discharge in a single distribution pipe with high pressure (6.5…8.0 bar).

Both types of irrigation systems deliver water to plants through sprinkling watering systems.

The irrigation plot with SPP can apply two classic watering methods (sprinkling + bed) by changing the pumps equipment mode. SPP pumping plant is equipped with pump for two pressure levels: a – high pressure level (P = 8 – 9 bars) for sprinkling watering; b – medium pressure (P = 4 - 5 bars) for bed watering. The irrigation plot will have two pipe networks, one for high pressure and one for medium pressure.

Pumping and pressure plants (SPP) have been equipped with two types of pumps:

- vertical diagonal pumps, VDF type (type removed later), MV (303 and 253) and MA 200;
- diagonal horizontal pumps type 8 and 12 NDS, RDN 200, AN 200 (150).

Monofilament pumping and pressure plants (SPPM) have been equipped with diagonal horizontal pumps NDS and RDN type. The pump equipment provides flow rates and pressures for applying the two watering methods (bed watering and sprinkling watering) used before 1989.

Most of the SPP irrigation plots were executed during 1970 - 1985 according to type projects (4824R-1984 Project). SPP and SPPM pumping plants were executed only with the infrastructure. The SPP constructive part, depending on water circulation is made of the following components: a - suction basin; b – grate; c – forebay - sand-clearing basin; d – screen chamber; e – suction tank; f – hydromechanical installation; g – electrical transformer substation building (*figure 2*).

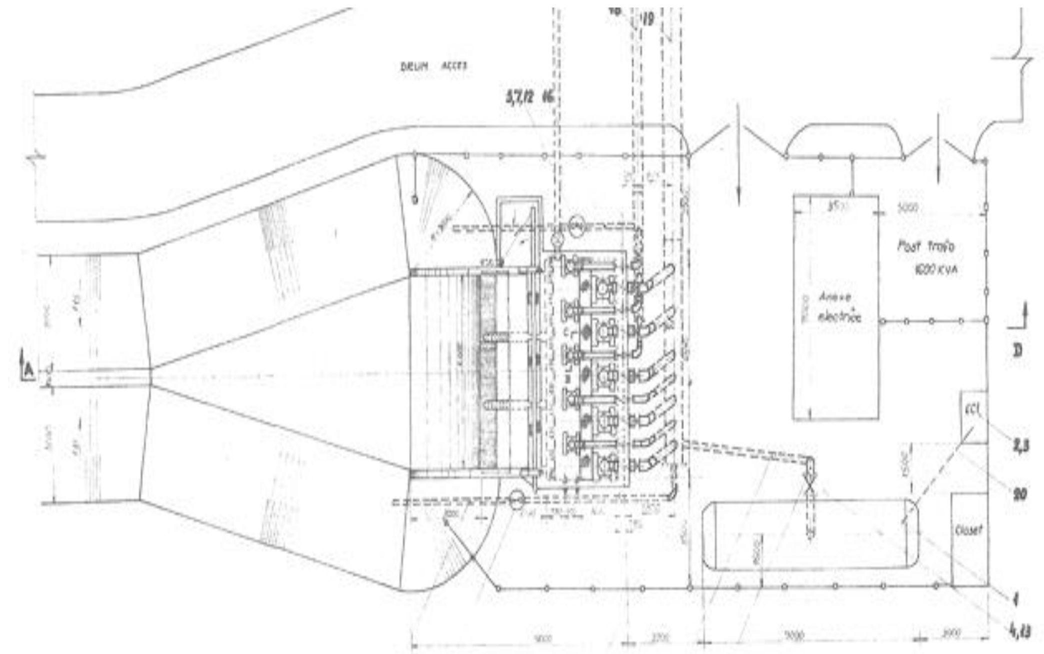

Figure 2 **SPP pumping plant constructive structure (top view): a - suction basin; b – grate; c – forebay - sand-clearing basin; d – screens; e – suction tank; f – hydromechanical installation; g – electrical transformer substation building.**

The SPP constructive structure is made of reinforced concrete and metallic confections. The pumping aggregates, the SPP hydraulic installation and the screen installation are placed on top of the tank covering slab.

The term **EXPERTISE** designates a technical action of scientific investigation, using special resources (studies, experiments, calculations, analysis etc.) to determine a certain aspect of the researched subject. The expertise can be technical, financial, medical, legal etc.

The legal basis for the development of a technical expertise in the constructions and installations field is given by Law 10/1991 (updated) and HG 925/1995 (updated). Thus, „A quality **technical expertise** is a complex activity involving, as required, **research, experimentation or testing, studies, surveys, analysis and evaluations** necessary for knowing the **technical state** of an existing construction or the way in which a project follows the legal requirements, in order to substantiate the intervention measures”.

The activity is carried out by **qualified technical experts**, certified by the speciality minister. Technical expertise is required when a legal regulation or a state body with control attributions in the constructions and installations quality field stipulates it, or when a particular situation requires it. Technical expertise is required in the following situations:

A – solving situations which occur at existing constructions

- is case of disasters or accidents due to natural phenomena, human actions or technological activity;

- in order to determine, at any stage, the technical state of the construction, respectively of the installation and to assess its capacity to meet the legal requirements.

B – solving legal disputes regarding the technical quality of some projects, or of the execution of some construction and installation works.

According to the legislation in effect, the hydrotechnical objectives with a certain socio-economical importance must be examined at an interval of 5...7 or 10 years within the importance category. For land reclamation hydrotechnical works, whose constructive and functional state was affected by a number of disasters and calamities over a certain time period, technical expertise is required in order to analyse the operational reliability state.

The technical expert must have a special professional and scientific background, based on the following: a scientific research activity of the expertise fields; a complex design activity at project manager level for the examined constructions and installations; a technical documentation and knowledge of legislation, standards, design and execution norms.

The expertise is carried out at the current investigative methods level and includes both the analysis of existing information (the initial execution project, execution data, changes made during the execution, operational behaviour, construction time evolution etc.) as well as studies, post calculation notes, analysis etc., on the actual values of the parameters determined to asses the work's safety state. In the case of hydrotechnical objectives, through content and approach way, the technical expertise must comprise two stages: preliminary expertise and final expertise. An intermediary step can be interposed between them, made of studies and research needed to clarify some structural and functional situations of the examined objective (Luca M., 2015a).

The first stage of the expertise analyses the current technical state of the constructions and installations through the following operations:

- analysis of design technical documentation, documents from execution time and operational period;
- field investigation with structure inspection, in situ tests, structural and functional parameter measurements, operational manoeuvres and samples selection;
- interpretation of data collected and drafting a preliminary report on the buildings and installations' structural and functional state after an operational period, or from other cases;
- highlighting the risk situations in the constructions and installations' running, in accordance to their actual technical state.

The intermediate or second stage contains a number of studies defining constructive and operational features. In the SPP case a simulation of the functioning under conditions of wear and aging of elements from the hydromechanical line (pumps, electric motors, pipes, fittings and fixtures) is carried out. The simulation includes an energetic analysis to determine the energy consumption per volume unit of pumped water.

Functional state of the technological line analysis of hydro energy balance is achieved by pumping aggregates. Energy balance is drawn up based on measurements made pumping station for various operating situations. The main parameters considered in the analysis (Luca M., 2000; Exharhu M., 1997, Burchiu V. *et al*, 1982):

- energy used for pumping

(1) $$E = P_a \cdot T \ ,$$

(2) $$E = \frac{2{,}725 \cdot k \cdot V \cdot H}{\eta_a}$$

where E is energy , kWh; V - the volume of water pumped thousand m^3; H - to the head, m ; η_a - yield pumping aggregates ; P_a - aggregate installed capacity pumping; T - pumping time; k - coefficient which takes into account energy consumption in auxiliary facilities;

- the specific energy consumption for transport under load H unit volume pumped:

(3) $$e = \frac{2{,}725 H}{\eta_a} \cdot \left(\frac{kWh}{1000\, m^3 \cdot m} \right)$$

- unit specific energy consumption per unit volume of water under a load H = 1.0 m:

(4) $$e = \frac{2{,}725}{\eta_a} \cdot \left(\frac{kWh}{1000\, m^3 \cdot m} \right)$$

- yield pumping aggregates:

(5) $$\eta_a = \eta_T \cdot \eta_m \cdot \eta_p \cdot \eta_h \ ,$$

η_a where is the total yield; η_T - yield of electrical transmission; η_m - electric motor yield; η_p - pump yield; η_h - hydraulic yield.

Relationships (3, 4 and 5) are applicable only if the pumps are identical.

Equipment for the pumping station with old and new proposed parameters will determine the operating point (Q_F, H_F, n, D) (Burchiu V. *et al*, 1982; Luca M., 2000).

The second or third stage if an intermediate stage exists consists of the "Technical expertise report", which includes the expert's conclusions regarding the structural and functional state of the objective assessed. The expert establishes the work's safety state, taking into account the results of the additional investigations and proposes the operational conditions for the next time period. Also, the expert presents the constructions and installations directions for rehabilitation, redesign and restoration etc. (Luca M., 2015a).

The pumping stations technical expertise execution is customised according to known data from technical design documentation, the current field situation, the additional studies to be carried out and, finally, the expert's technical and scientific competence. A number of peculiarities of the SPP technical expertise are presented in the following examples.

The technical expertise conducted for SPP1b from Soloneţ-Nord irrigation system indicated the current state of the constructions and installations after 35 years of operation (Luca M. *et al*, 2016). The analysis considered the constructive and functional structures presented in the selected design sheets, the field situation, field inspection results and additional studies conducted.

SPP1b pumping plant is a classic execution design for sprinkling and bed irrigation plots. The irrigation plot has a surface of 1428 ha. The pumping plant was designed in 1980 and put into operation in 1983. The pumping station was designed with two pressure levels and equipped in accordance (*table 1*).

- pumping level I for sprinkling irrigation with Q = 0.800 m^3/s and P = 8.50 bar;
- pumping level I for surface watering (bed irrigation) with Q = 0.200 m^3/s and P = 4.50 bar.

Table 1

SPP 1b pumping aggregate parameters

Vertical pump MV 253 x 4	Vertical pump MA 200 x 5
Q = 504 m^3/h	Q = 230 m^3/h
P = 8.50 bar	P = 4.50 bar
n = 1500 rot/min	n = 1500 rot/min
N = 200 kW	N = 55 kW
U = 380/660 V	U = 380/660 V
η = 60%	η = 55%
5 pumps	5 pumps

The technical expertise did not have access to the construction's Technical Book, respectively the execution project (technical report, execution sheets and calculus notes). In this situation, the expert had to conduct documentation on similar pumping stations and analyse execution type projects. The SPP1b constructive structure expertise highlighted the following:

A – Constructive structure:

- the structural state of the channel – station tank connection area is unsatisfactory due to the concrete slabs' high degree of degradation;
- the constructive structure of the tank has areas with degradation of the protective plastering and the reinforced concrete exterior and interior walls; natural and anthropic actions on site have led to the fissuring of the constituent wall layers; during the execution phase material stripping was performed and deeper degradations were highlighted in the tank's reinforced concrete wall;
- the slab covering the tank has degradation areas due to the removal of the cement plaster and the fissures and cracks in the reinforced concrete structure (*figure 3*);
- the metallic confections included in the tank structure are corroded, worn out and degraded by the climatic factors and human action; the aging of the material is accentuated;
- tank entrance grate no longer exists, being replaced by a non-functional improvisation

The hydromechanical installation (pumping aggregate and hydraulic circuit), the hydraulic shock protection, the energetic installation, electric panel building, electrical transformer substation, the screen installation were presented in detail in the paper (Luca Al. L. *et al*, 2016). The technical expertise characterises the SPP1b pumping plant structural and functional state as unsatisfactory. The expert recommended a rehabilitation works program which was completed in 2016.

Figure 3 **Degradation state of the SPP1b pumping plant tank covering slab (Luca Al., 2016)**

It should be noted that the SPP irrigation plots have not been equipped with measuring equipment for received and delivered flows.

The expertise carried out at „Berezeni plot 16" from Albiţa Fălciu Complex Irrigation and Drainage Facility revealed the total unsatisfactory state of the SPP 16 and hydromechanical line constructive structure (*figure 4*) (Luca M., 2015).

Figure 4 **SPP1b Berezeni pumping plant infrastructure degradation state (Luca M., 2015)**

The SPP constructive structure is degraded at walls level, where it has fissures and cracks. The hydromechanical line still included VDF type pumps, which were eliminated during the 1980s.

Another technical expertise has analysed the sprinkling irrigation plots equipped with monofilament pumping plants. A typical example is „Doniceasa – Fălciu Plot 7", equipped with SPPM for sprinkling. Details on Doniceasa – Fălciu Plot 7 layout and equipment are presented in the paper (Luca M., 2015). The technical expert did not have access to any documentary source (the Construction's Technical Book) on the irrigation plot execution and operational procedures. The irrigation plot is currently privately operated.

The expertise carried out at monofilament pumping plants has highlighted the following conclusions:

- the constructive structures made of reinforced concrete (the pumping aggregates foundation, anchoring blocks, valve homes) are in a state of total degradation (*figure 5*);

- the pumping aggregates are completely degraded, taking into account the equipment with 12 NDS and RDN 200 pumps, manufactured in the 1960s;

- the SPPM pumping plants are not equipped with priming installations (in the initial stage, the SPPM were manually primed);

- the SPPM hydraulic system is degraded and has an outdated service life (*figure 5*);

- the electrical motors driving the pumps are completely outdated by the current technical level; actually, SPPM has the equipment with which it was put into service (the 1970s).

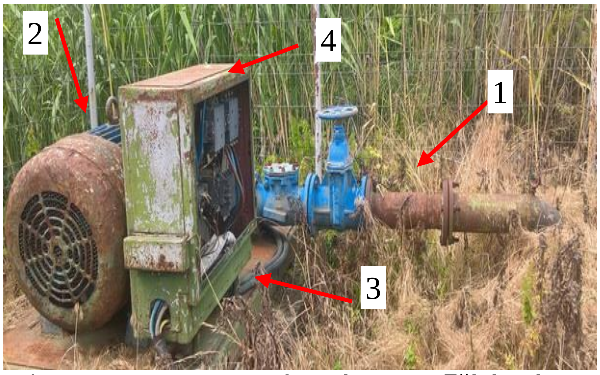

Figure 5 **Current state of Doniceasa – Fălciu Plot 7 SPPM: 1 – hydraulic installation; 2 – electrical motor; 3 – foundation of pump; 4 - electric panel (Luca M., 2016).**

In this case, the expert has proposed two SPPM rehabilitation and reengineering options. One of the options included the priming installation into the hydromechanic installation system. Also, the expert proposed a SPPM conversion option from horizontal to vertical pumps, with a radical change of the constructive structure (Luca M., 2015).

A similar case, SPPM equipped with horizontal pumps, was examined at a number of irrigation plots from Great Brăila Island. The irrigation plots at this location have the same structural and functional state mentioned earlier at Doniceasa-Fălciu Plot 7. In this case, the expert suggested the conversion of SPPM with horizontal pumps into modern hydrotechnical structures with vertical pumps.

CONCLUSIONS

1. Irrigation plots are the most frequently rehabilitated components of old irrigation systems, situation which require their examination on all structural and functional components.

2. The technical expertise is a technical and scientific work through which the expert technically analyses the SPP constructions structural state and suggests rehabilitation and modernisation options.

3. Through technical expertise, the expert technically and energetically analyses the structural and functional state of SPP hydromechanical installations, depending on the degradation and aging degree.

4. The technical expertises conducted have shown major degradation at pumping station tank construction, some of which are located in the ground and are hard to see.

5. The rehabilitation of SPP pumping plants must be done in a complex way, at the level of current technologies, with the introduction of monitoring and automation system of the operational process.

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