DOI:10.5937/IIZS25110P

THE ROLE AND IMPORTANCE OF CONDENSATE PUMPS IN THE OPERATION OF A 110 MW COMBINED HEAT AND POWER PLANT

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Abstract: This paper analyzes the design, function, and operation of the condensate pumps I0 and II0 within the thermal power and heating plant (CHP) with a nominal electric capacity of 110 MW and a thermal output for district heating of 140 MWt. The facility is designed for the combined production of electricity and heat. The I0 condensate pumps, vertical multistage centrifugal units, ensure continuous circulation of condensate from the turbine condenser through the regenerative heating system and return the condensate to the deaeration tanks. The II0 condensate pumps, horizontal multistage centrifugal units, play a critical role during system startup phases and in the transfer of feedwater between tanks of varying pressure levels. The study presents the technical parameters of these pumps, describes startup modes and automatic control systems, and emphasizes their importance for the safe, efficient, and continuous operation of the plant. Based on pipeline diagrams, hydraulic losses and the required pump efforts under different operating conditions are analyzed. The conclusion highlights the significance of proper sizing, control, and maintenance of condensate pumps to ensure the reliable operation of the entire thermal energy system.
Key words: condensate pump, thermal power plant, CHP, centrifugal pump, condenser, feedwater, energy system

INTRODUCTION

Combined heat and power plants (CHP) represent key energy systems that enable the simultaneous production of thermal and electrical energy within a single integrated process, thereby achieving high energy efficiency and rational fuel utilization. In modern energy facilities, particularly those designed for district heating in urban areas, the reliable operation of auxiliary systems is of critical importance, with condensate pumps playing a particularly prominent role [1, 2].

Condensate pumps, as components of the condensation system in thermal power facilities, are responsible for collecting condensate from the turbine condenser and transporting it through regenerative heating devices to the deaeration system. This enables a closed-loop feedwater cycle, which reduces energy losses and enhances operational safety [2, 4]. In the facility under study, two groups of condensate pumps are employed: vertical condensate pumps (I0), which operate in continuous condensate circulation mode, and horizontal condensate pumps (II0), which play a crucial role during plant startup and in supplying feedwater to the boilers [1, 5].

This paper focuses on the analysis of their design, technical characteristics, operating principles, and functional significance within the overall thermal energy process. Special attention is given to the hydraulic characteristics of the system, automation in operation, and the importance of regular monitoring in order to ensure the optimal and uninterrupted functionality of the CHP system [6, 7].

MATERIAL AND METHODS

The analysis presented in this paper is based on the technical documentation and the actual configuration of a Combined Heat and Power (CHP) plant with a nominal electrical capacity of 110 MW, designed for the cogeneration of electricity and heat [8]. Special attention is given to the I0 and II0 condensate pumps, which are essential components for condensate circulation and for ensuring the reliable operation of the boiler feedwater system.

The methodological approach is structured through the following steps:

- Technical analysis of pump construction – Performed based on manufacturer documentation and specifications of the installed units.
- Analysis of operating modes and automation – Involves evaluation of startup logic, minimum and maximum flow rates, system pressures, and activation of backup pumps, along with the interpretation of the operation of electrical fittings and control valves.
- Hydraulic analysis – The characteristics of the discharge pipelines for both condensate pump systems were examined, including elevation differences, pressure drops, static head variations, and required control resistances.
- Operational monitoring and control parameters – Includes analysis of parameters monitored in real time by the operating personnel.

The application of these methods enables a systematic assessment of the efficiency, reliability, and energy-related role of condensate pumps within the overall CHP process.

I0 Condensate Pumps

The I0 condensate pumps (Fig. 1) represent key components of the condensate circulation system in the CHP plant. These are vertical, multistage centrifugal pumps of the type 125-CJAV-265-15/7-LU-OO-F, equipped with radial impellers. The main technical specifications of each pump are presented in Table 1 [8].

Fig. 1. *I0 Condensate Pumps*

The primary function of these pumps is to extract condensate from the turbine condenser and convey it through the low-pressure regenerative heating system, which includes the gland steam condenser, the small consumers' steam condenser, and the low-pressure heaters of stages I and II. The system includes three I0 condensate pumps, two of which operate under normal conditions while the third serves as a standby unit. The pumps are directly connected to the turbine condenser, and their total capacity corresponds to the maximum steam inflow under full condensation mode.
To ensure operational stability, the system is designed so that the minimum condensate flow is maintained via recirculation back to the condenser, while water is also delivered from the pump discharge to cooling and sealing systems. The pump startup process requires the condensate level in the condenser to reach at least one-third of its volume, which is automatically regulated via a control valve on the discharge line.
The pump startup sequence involves the following steps:

1. The selected pump is activated with the shut-off electro valves in the closed position.
2. After a 30-second delay, both the shut-off valve and the control valve on the minimum condensate recirculation line are opened. This enables partial flow return to the condenser, ensuring stable cooling of the gland steam condenser and the small consumers' condenser with a minimum flow of 80 t/h.
3. Upon reaching a discharge pipeline pressure of 0.8 MPa, the valves to the main line are opened, while the minimum flow recirculation line is gradually closed.
4. When the condensate flow reaches 90 t/h, the second pump is automatically activated, and if it exceeds 170 t/h, the third (standby) pump is also engaged.
5. Conversely, when the flow drops below 155 t/h, the third pump is deactivated, and if it falls further below 80 t/h, only one pump remains in operation.

During pump operation, continuous monitoring of key parameters is performed:

- System sealing and cooling water temperature (the outlet temperature is allowed to be 10–15 °C higher than the inlet),
- Lubrication and bearing temperatures (must not exceed 75 °C),
- Motor temperature and load (monitored via amperage),
- Drive power increase, which may indicate increased flow or mechanical irregularities,
- Condensate level in the collector,
- Minimum flow through the gland steam and small consumers’ condensers (≥ 80 t/h).

Table 1. *Technical Characteristics of I0 Condensate Pumps*

Parameter	**Value**
Pump type	125-CJAV-265-15/7-LU-OO-F
Pump configuration	Vertical, centrifugal, multistage
Impeller type	Radial
Number of installed pumps	3 (two operational + one standby)
Flow rate	125 m³/h
Head (specific energy)	1334 J/kg
Motor power	70 kW
Motor speed	1470 rpm
Minimum condensate level required for startup	1/3 of condenser height
Minimum flow required for condenser cooling	80 t/h
Activation of second pump	When flow reaches 90 t/h
Activation of third (standby) pump	When flow reaches 170 t/h
Deactivation of third pump	When flow drops below 155 t/h
Deactivation of second pump	When flow drops below 80 t/h
Maximum permissible bearing temperature	75 °C
Allowable increase in cooling water temperature	10–15 °C compared to inlet temperature

II0 Condensate Pumps

The II0 condensate pumps are horizontal, multistage centrifugal units of type 250-CHT-350-48/3-OU-00-F/2E. These pumps are essential for the recirculation and transfer of feedwater between tanks operating at different pressures within the thermal power cycle. The main technical characteristics of the pumps are presented in Table 2.
During cold startup of the thermal plant, the II0 condensate pumps enable circulation of feedwater from the low-pressure tank via the auxiliary line. This recirculation continues until the required feedwater temperature in the system is achieved.
Under normal operating conditions, the II0 condensate pumps transfer water from the low-pressure tank (temperature up to 140 °C, pressure 0.4 MPa) to high-pressure tanks, which then supply the boilers. These pumps are also used to fill boiler units prior to block startup, using the same discharge and auxiliary lines.

Typically, two condensate pumps are in operation, while the third serves as a standby and is automatically activated if needed. The startup sequence of a pump begins with the control valve on the discharge pipeline in a closed position. After a brief delay, the shut-off electrovalve on the minimum flow recirculation line opens, allowing the return of condensate to the low-pressure tank. Once the discharge pressure reaches 0.8 MPa, the shut-off and control valves toward the main line open sequentially.
During pump operation, continuous monitoring and control of the following parameters is essential:

- Equipment functionality and sealing integrity
- Bearing temperature (maximum allowed: 75 °C) and lubrication
- Pressure and temperature at the pump discharge
- Activation of the standby pump when flow exceeds approximately 340 t/h
- Deactivation of the standby pump when flow drops below 290 t/h
- Activation of the recirculation loop when flow falls below 86 t/h, triggering closure of electrovalves to the main line and return of water to the low-pressure tank

Figure 2 illustrates the actual configuration of the II0 condensate pumps [8]..

Table 2. *Technical Characteristics of II0 Condensate Pumps*

Parameter	Value
Pump type	250-CHT-350-48/3-OU-00-F/2E
Manufacturer	SIGMA Lutin, Czech Republic
Pump configuration	Horizontal, multistage, centrifugal
Number of installed pumps	3 (two operational + one standby)
Flow rate	317.5 m^3/h
Head (specific energy)	870 J/kg
Motor power	121 kW
Motor speed	1480 rpm
Working fluid	Feedwater (up to 140 °C, 0.4 MPa)
Function during cold startup	Recirculation from the low-pressure tank via line NB02
Function during normal operation	Transfer to the high-pressure tank and boiler filling
Activation of standby pump	At flow rate ≥ 340 t/h
Deactivation of standby pump	At flow rate ≤ 290 t/h
Activation of recirculation (minimum flow)	At flow rate ≤ 86 t/h
Maximum permissible bearing temperature	75 °C
Startup parameter (discharge pressure for valve opening)	≥ 0.8 MPa

Fig. 2. *II0 Condensate Pumps*

RESULTS AND DISCUSSION

The analysis of the operation of I0 and II0 condensate pumps within the 110 MW Combined Heat and Power (CHP) plant indicates that these units play a critical role in maintaining continuous condensate flow and ensuring the stable operation of the feedwater and boiler sections of the system.

The I0 condensate pumps, designed as vertical multistage centrifugal units, facilitate efficient condensate recirculation from the turbine condenser through the low-pressure regenerative heaters. Their automatic operation, based on condensate quantity and system pressure, enables the dynamic inclusion of additional pumps when needed. This ensures optimal condenser cooling and prevents thermal stress in the system. The minimum required flow for safe condenser cooling (80 t/h) is reliably maintained through the minimum recirculation system, even under variable turbine operating conditions. Notably, the automated startup sequence and pump control eliminate the need for manual intervention, significantly improving operational safety.

The horizontally configured II0 condensate pumps prove essential during the cold startup phase, providing recirculation and thermal conditioning of feedwater in the low-pressure tank via the auxiliary line. Under normal operating conditions, they transfer water to the high-pressure tank and enable boiler filling prior to turbine engagement. Full automation is also implemented here—the standby pump is activated or deactivated depending on flow thresholds ($\geq$ 340 t/h and $\leq$ 290 t/h). In the event of a critical flow drop, the system automatically switches to minimum recirculation mode, protecting the equipment from potential damage.

For the selected pipeline route from the condenser to the deaerator in the low-pressure tank, a characteristic pipeline curve was developed and analyzed, taking into account all hydraulic resistances. This enables precise estimation of the required pump head under real operating conditions (Fig. 3).

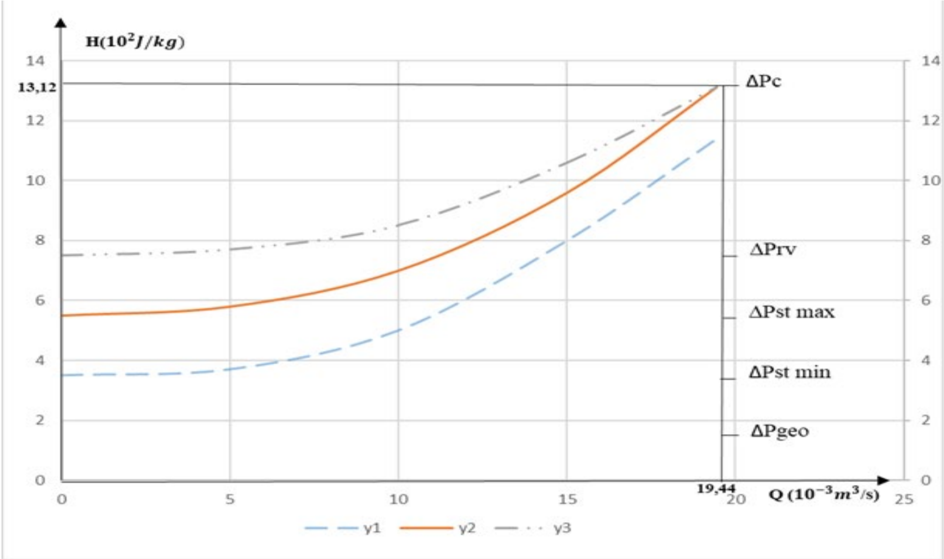

Fig.3. *Discharge Pipeline Characteristics of First-Stage Condensate Pumps*

y1 – Minimum pressure at deaerator; y2 – Flow through the deaerator proportional to pump flow; y3 – Maximum flow through the deaerator
ΔPgeo (bar) – Difference in geodetic elevation
ΔPst (bar) – Difference in static pressure
ΔPrv (bar) – Minimum pressure drop across the control valve
ΔPc (bar) – Pressure drop in the pipeline

Figure 4 shows the pipeline curve for the feedwater route from the low-pressure to the high-pressure tank. This diagram provides insight into the system's hydraulic resistance and enables precise sizing of pumps and control equipment.

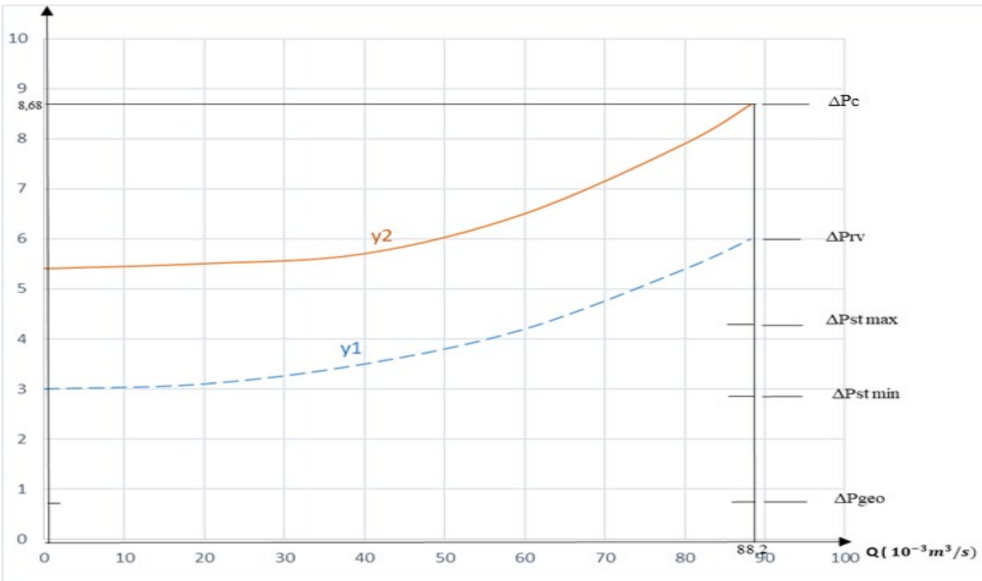

Fig 4. *Discharge Pipeline Characteristic Curve for Second-Stage Condensate Pumps*

y1 – Minimum pressure in the deaerator
y2 – Maximum pressure in the deaerator
ΔPgeo (bar) – Geodetic elevation difference
ΔPst (bar) – Static pressure difference

ΔPrv – Minimum pressure drop across the control valve
ΔPc (bar) – Pressure drop in the pipeline

The characteristic pipeline curves analyzed for both pump groups confirm that all hydraulic resistances, elevation differences, and pressure drops were adequately considered during system design. This results in optimal pump sizing and balanced load distribution across all active units.
In conclusion, the performance of the I0 and II0 condensate pumps in the CHP plant demonstrates high reliability and efficiency. The automation system, together with the technical pump configuration, ensures stable condensate transfer, flexible operating regimes, and protection of critical components. Such a solution significantly enhances the overall energy efficiency and operational safety of the thermal power unit. Fig. 5 presents a graph illustrating pump activation as a function of condensate flow.

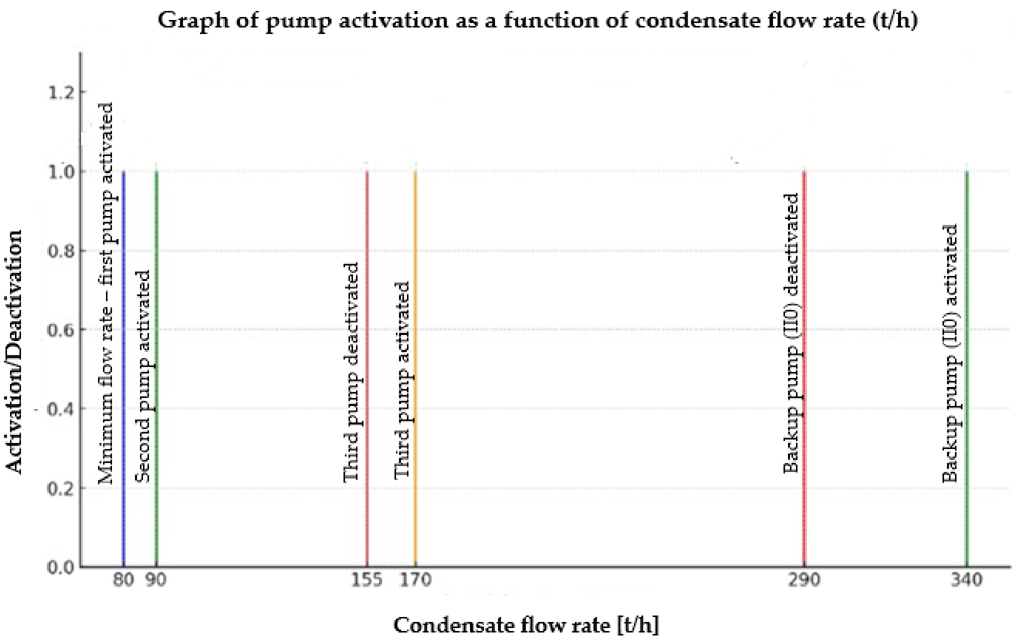

Fig. 5. *Pump activation graph as a function of condensate flow rate.*

CONCLUSION

Condensate pumps constitute a critical component of the condensate circulation system in thermal power plants, directly impacting the efficiency, safety, and operational continuity of the entire plant unit. The analysis of the operation of pumps I0 and II0 within the Combined Heat and Power Plant (CHP) demonstrated that they are functionally, technically, and hydraulically well integrated into the process of thermal and electrical energy production.
The vertical condensate pumps I0 ensure a stable flow of condensate through the regenerative section of the system, enabling optimal heat utilization and the return of condensate into the cycle. Their automation and recirculation system allow adaptation to variable turbine operating regimes, thereby enhancing the overall system reliability. Conversely, the horizontal condensate pumps II0 play a crucial role during plant startup phases and in the distribution of feedwater between reservoirs at different pressure levels, including boiler filling prior to startup.
The implementation of automated start-stop regimes, along with precise flow and pressure regulation, ensures that pump operation is fully synchronized with plant demands, eliminating

the need for manual adjustments. This approach contributes to a high degree of operational safety and minimizes the risk of potential downtime [3, 9].
In conclusion, a properly designed and managed condensate pump system is essential for the efficient and reliable operation of combined heat and power plants. The experience gained at the CHP plant can serve as a model of best practice in the design and management of auxiliary systems within modern thermal power facilities.

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