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Influence Of Pumping Unit Start-Up Modes On The Nature Of Hydraulic Hammer In Pressure Water Pipelines

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Abstract: The causes of the influence of the methods of starting the pumping unit on the probability of occurrence of hydraulic hammer in pressure sewer pipelines are investigated. It is noted that the effectiveness of their application depends on their correct choice. The sequence of operations for starting and stopping the pumping unit and methods for regulating operating parameters are described. Measures are proposed to prevent hydraulic shocks resulting from the start-up of pumping units.

Key words: sewage pumping station, pressure pipeline, water hammer, power supply system, wastewater inflow schedule, stepwise mode, receiving tank, plunger, protective equipment.

INTRODUCTION

Prof. Zhukovsky Nikolai Egorovich, a Russian scientist and the father of hydrodynamics, made the discovery of the water hammer phenomena between 1897 and 1899. This phenomenon is defined as a sudden rise in pressure in a liquid-filled system with a correspondingly quick change in flow rate over a brief period of time. Engineering systems may suffer permanent damage as a result of this phenomena.

Experience with the operation of sewage pumping stations (SPS) has shown that the main instances of pumping unit damage and accidents take place during transient processes, starts and stops, which, depending on the pumping station's operating schedule, may occur several times per day, as well as during emergency electric motor shutdowns from the power system [1,2].

Dynamic electromagnetic transient processes, as well as hydraulic shocks during startup that wear out and damage the mechanical components of the equipment and pipeline joints, happen when the units are turned on and off. The following issues occur repeatedly during startup: an increase in the magnitude of motor currents and torques, voltage deviation, motor heating, and extra losses, which shorten the technical life of pumping units and all equipment collectively [3,4].

Urban wastewater pumping units were the subject of investigation in this article. The start-up modes of the units, which were taken into consideration during the research at the sewage pumping station GKNS-1, which is located in the city of Namangan in the Namangan area of the Republic of Uzbekistan, were disturbing acts on the object. There are four pumping units at this station, each having an 8 MW capacity. Turning the units on and off to regulate the operation of the pumping units is unsafe and inefficient.

The way pumping units are started affects the possibility of a water hammer, as various studies have demonstrated [5,6].

There are two ways to turn on pumps: by opening or closing a valve on the pressure pipeline. The valve on the suction pipeline must always be open for any starting method.

Under typical circumstances, it is advised to shut off pumping units by closing a valve on the pressure pipeline.

The open pressure valve causes the units to shut down suddenly in the case of an emergency power interruption. As a result, it is advised to implement steps during operation to lessen the impact of water hammer if they are not already included in the design. These precautions include setting up slow-landing check valves, running water through the pump in the other direction, etc.

Pump shut-off and control valve designs (such as valve, butterfly valve, conical valve, etc.) are also taken into consideration when deciding on a beginning technique for pumps. The producers of pumps, electric motors, and switching devices (switches, contactors) control the number of pumping units that may be turned on and off.

In the 1970s, the city of Namangan had a significant increase in the number of water pumping stations. At that time, the major pumps' synchronous high-voltage electric motors (1600 kW, 6–10 kV) had independent electric machine exciters installed on the electric motor shaft. The way pumping units are started has an impact on the likelihood of water hammer, according to research [7]. Therefore, circuits for the power plant's auxiliary demands (0.4 kV) were not meant for the exciters of the main units but rather for the power supply of auxiliary mechanisms and systems. At the KNS, even in the presence of four high-voltage inputs from an external power source, two auxiliary transformers were often built, supplying a two-section 0.4 kV auxiliary switchboard. If each unit had its own exciters, such layouts were extremely acceptable. Later on, thyristor exciters were added to big SPS synchronous electric motors and were powered by two-section 0.4 kV auxiliary switchboards. As a consequence, it was discovered that the auxiliary requirements schemes of major pumping stations and external power supply schemes had different levels of dependability. These interruptions in the power supply to the pumping units also resulted in hydraulic shocks in the pumping station's pressure communications.

The "Standard Instructions for the Operation of Water Supply and Sewage Pumping Stations" are often followed while operating pumping stations, and were authorized by the head engineer of the production department of the water supply and sewerage sector.

Direct start-up of a pump is often prohibited in municipal sewage systems, subject to the technological requirements for maintaining the pumping station.

This is explained by the fact that the start-up of pumping units equipped with an adjustable electric drive is carried out with a given acceleration of the speed of rotation of the pump impellers. If the pumping unit is equipped with an unregulated electric drive, the unit is started with a closed valve followed by a smooth opening of the pressure valve [9,10].

The nature of hydraulic shocks is also influenced by the operating mode of the pumping station. Large and large plants are characterized by continuous operation with variable supply, corresponding to the wastewater influx schedule. During normal operation, the pressure water conduits of these stations are constantly filled with wastewater. Although the supply schedule for pumping stations with emergency distribution tanks differs significantly from the inflow timetable, their pressure water pipes are normally supplied with wastewater as well. The use of an adjustable electric drive or control valves allows the supply of big and large pump stations to vary smoothly. Stepwise working mode is a characteristic of small pump stations. When the pressure valve is open, their pumps automatically switch on and off in response to variations in the wastewater level in the receiving tank. The pumps run until the waste level in the receiving tank reaches the minimum level that has been set. The operation time (10–20 minutes) is dependent on the wastewater intake. The check valves close as soon as the system shuts off.

The pumps are restarted when the receiving tank has been filled to the required level. This happens 30 to 40 times every day [11].

When selecting shockproof protection for the systems under consideration, it is important to keep in mind that wastewater is a heterogeneous and multiphase medium, and that the parameters of pressure pipelines for wastewater disposal systems differ in many ways from those for systems transporting clean drinking water.

It is advised to consider the presence of solid, biological, and gas inclusions in wastewater when calculating the hydraulic shock in pressure water pipelines because they have a significant impact on the nature of the hydraulic shock and affect the shock wave's speed of propagation. The hydro-physical-chemical system of wastewater is more intricate. First off, wastewater is a heterogeneous or multiphase medium in terms of the number of distinct stages of aggregation (phases) it includes. In addition to liquid, it also contains numerous undissolved gases and particles. Different from the movement of a homogeneous liquid is the movement of a flow with solid particles and undissolved gases. The existence of a solid component in wastewater shows the necessity to consider the flow's transportation capacity; the value of hydraulic resistance may alter based on the quantity and size of solid particles; Additionally, if a flow contains a little bit of solid phase, the hydraulic properties of the fluid movement will govern how it moves.

According to research [12], the elastic characteristics of the system are most severely impacted by the presence of undissolved gases in the pressure flow, which impacts a quick shift in hydrodynamic parameters during hydraulic shocks.

Second, the components that make up each phase of wastewater are quite different. Solid components can be both mineral and organic in origin, and the gaseous component can be made up of other gases besides only air, such as carbon dioxide, hydrogen sulfide, methane, etc. The presence of the majority of organic compounds in wastewater, which can quickly rot, causes the development of decomposition processes for these substances even during transportation to treatment facilities. Wastewater, unlike pressure flows, also contains sufficient amounts of biological impurities in the form of bacteria.

The choice of damper valves, air input and outlet valves, check valves with delayed landing, etc., to protect pressure pipes from water hammer is further complicated by these characteristics of wastewater composition. Additionally, several design elements of dynamic pumps are determined by the composition of wastewater: Clean water is supplied to the area of the stuffing box from the technical water supply under a pressure exceeding the pump pressure by 10-20 m; The internal cavity of the case is protected; the closed-type impeller is wider and has fewer blades than pumps pumping water for urban water supply; the blades are given a more streamlined shape; and there are hatches on the inlet pipe - audits through which the wheel and body can be cleaned in case of contamination with waste.

Water hammer is more likely to occur when a pumping unit or other device abruptly ceases. The majority of the time, they originate from both a malfunction of the pumping unit itself (such as a short circuit in the electric motor or power cable) and emergency scenarios involving the power supply system of the pumping station.

In the case of an accident (or the danger of one) involving a human that necessitates the quick stopping of the electric motor, it is also feasible that a water hammer may happen when the pumping units are shut off. Additionally, there are quite frequent cases when water hammers occur during automatic control of the SPS operating mode “by level”. In this mode, when the wastewater reaches a predetermined upper level, the units automatically switch on, and when it is pushed to a given lower level, the units automatically turn off. These implications are not very harmful for pumping stations with low-power units. However, such impacts represent a risk to sites where moderately strong units (250-320 kW or more) are deployed when pressure water pipes pass through rugged terrain [13]. The likelihood of a deep vacuum and, consequently, interruptions in the continuous flow of wastewater is significant in lengthy water pipes with difficult terrain.

The layout of water pipes and the terrain they are installed along have a big impact on how the hydraulic shock behaves. The pumping station's pressure pipelines often don't branch out, and their profile follows the topography. Consequently, their profile is defined by repeated drops and elevations in the level of geodetic markings of the earth. There is a considerable likelihood that a deep vacuum may form during an emergency shutdown of all pumping units in lengthy water pipelines with difficult topography, interrupting the uninterrupted flow of water [14].

Conclusions. Our analysis of the pumping station's operational modes while accounting for the local environment enables us to draw the conclusion that the techniques used to start pumping units, the operating staff's disregard for pumping station maintenance guidelines, a malfunctioning automated control system, or the presence of technological flaws in the project all have an impact on the probability of a water hammer.

Water hammer in the pressure drainage pipelines is also caused by a mismatch between the auxiliary requirements diagram and external power supply scheme of big pumping stations of ancient buildings.

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