Scientific and Social Research, 2024, Volume 6, Issue 7
https://ojs.bbwpublisher.com/index.php/SSR
Online ISSN: 2981-9946
Print ISSN: 2661-4332

Analysis of Fault Causes and Measures for Wastewater Systems with Poor Water Quality

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Abstract: In natural gas production facilities, separators are primarily used to separate produced water from the gas fields, which are then discharged into produced water ponds through the drainage system. Impurities in the produced water can cause malfunctions in the drainage system, severely affecting the monitoring and automated discharge of the water. This study investigates the causes of these system failures through onsite research. The study then proposes optimization measures such as improving the sealing ring materials of pneumatic drainage valves, enhancing the maintenance of these valves, adding filtration devices, and optimizing the structure of magnetic floats.

Keywords: Drainage system; Causes of failure; Optimization measures

Online publication: July 26, 2024

1. Introduction

Natural gas extracted from geological formations often carries impurities such as produced water and rock debris. Various chemicals are injected into the wells to ensure stable production, which blends with other substances during production, forming complex emulsified pollutants. To minimize the impact of produced water and pollutants on long-distance pipelines, separators are installed at gas extraction and transportation stations. These separators isolate the pollutant-laden produced water from the natural gas, which is then expelled through the drainage system for collection, treatment, and either discharge or reinjection [1]. According to onsite research, the drainage systems in gas fields are prone to high failure rates. The common response to these failures has been to increase maintenance, such as timely replacement of components when a drainage valve malfunctions. However, as failures become more frequent, maintenance cycles shorten, and costs increase [2]. Therefore, investigating the reasons behind the high failure rates of drainage systems and proposing effective measures to enhance their stability and reliability is crucial.

2. Composition of the drainage system at natural gas production sites

Currently, separator drainage systems often employ automatic drainage control systems, as shown in **Figure 1** [3]. The core component of the drainage system at a natural gas production site is the gas-liquid separator. Its principle relies on the difference in specific gravity between gas and liquid. When liquids flow with gases, the liquids, being heavier, tend to move downward due to gravity, while gases continue to flow in their original direction. In other words, there is a natural tendency for separation in a gravitational field, with the downward-moving liquids settling at the bottom of the separator, where they are collected and expelled through the drainage pipeline. Magnetic float level meters, widely used for their simple structure, precise measurements, and cost-effectiveness in industrial scenarios where liquid and interface levels need monitoring, are commonly used in separators. The core of a connecting rod-style magnetic float level meter is a stainless-steel measuring cylinder, cylindrical in shape, connected at both ends to the separator via flanges for easy access and disconnection, equipped with valve controls. The bottom of the cylinder is fitted with a drainage valve for easy maintenance or pressure relief. Inside the cylinder, a magnetic float with an embedded permanent magnet influences the external magnetic flip panel display, showing the fluid level for easy monitoring. Pneumatic drainage valves, often using ball valves for on-off control, are utilized with downstream valve sleeves for adjusting the amount of drainage. The pneumatic drainage valve mainly consists of a pneumatic actuator and the valve body itself. The valve body is typically designed as a ball valve, allowing for 90-degree rotational movement. The pneumatic drainage valve is operated by a pneumatic actuator, which drives the rotation or movement of the valve body. Known for their ease of operation and quick response, pneumatic drainage valves are widely used in the oil and natural gas industry.

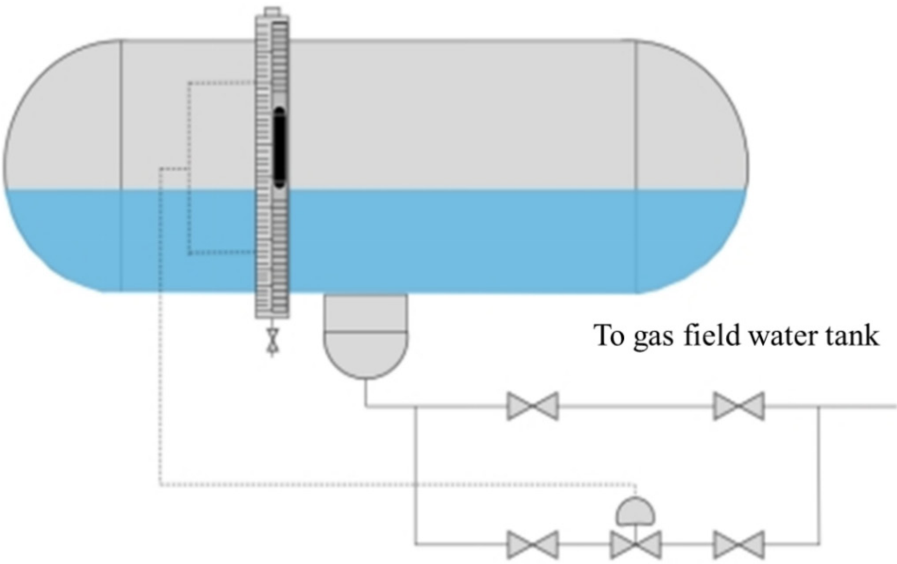

Figure 1. Separator wastewater system

2. Current application of wastewater systems

Currently, with deteriorating water quality, existing wastewater systems frequently malfunction, significantly impacting the stable, reliable, and safe operation of stations. The main issues with wastewater systems in natural gas production stations are as follows:

During colder seasons, magnetic float level gauges at gas production stations often experience blockages causing inaccurate displays due to obstructions.

The lack of filtration devices in the gas field's water drainage process makes electric ball valves susceptible to impurities. Frequent switching of these valves often leads to internal leaks within the valve cores, resulting in high maintenance costs. Additionally, impurities in the pipelines flow into steam traps and are filtered by internal nets. If the accumulated debris is not promptly cleared, it can cause the steam traps to malfunction, leading to poor or no drainage.

3. Analysis of wastewater system failures

To investigate the high failure rate of the wastewater system, a survey was conducted at 56 production stations. The results, as shown in **Figure 2**, indicate that the main causes of magnetic float failures are debris adhesion and damage to the float itself; valve failures are primarily due to operational difficulties and internal leaks. Detailed analysis results are as follows.

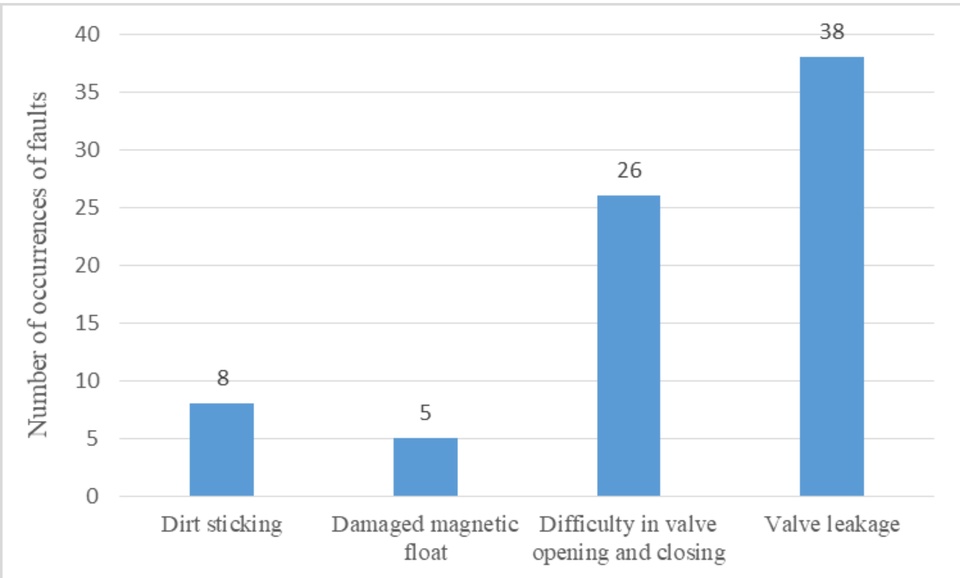

Figure 2. Failure cause statistics

3.1. Analysis of magnetic float obstructions

Although magnetic float level gauges theoretically provide accurate liquid and interface level detection, many such devices display inaccuracies, showing erratic level changes or linear trends. The primary reason is the adhesion of debris to the magnetic float, which is the most common cause of malfunction during operation.

The permanent magnet inside the magnetic float acts like a magnet, attracting particles in the medium. In stagnant or slow-flow environments, these impurities gradually accumulate on the surface of the float. Over time, this buildup increases, eventually causing the float to sink and lose its detection function.

Even if the debris does not cause the float to sink, it can restrict the float's movement within the measuring cylinder, leading to obstructions or jamming. If impurities also accumulate on the inner walls of the cylinder, it further increases resistance to the float's movement, exacerbating the problem and affecting the accuracy and reliability of level monitoring.

Modern magnetic floats often feature a hollow design. While this design reduces the weight of the float and enhances its buoyancy, it also poses certain risks. In complex and variable production environments, especially in the presence of corrosive media, the outer shell of these hollow-designed floats is prone to corrosion. Once corroded and cracked, surrounding liquids can quickly seep inside the float. This infiltration alters the original buoyancy balance, directly compromising the measurement system.

3.2. Analysis of drain valve obstructions

Impurities in gas field water accumulate between the valve sleeve and core, making the operation of the drain valve difficult. Moreover, because the ball valve internals often accumulate some impurities, the valve may experience varying degrees of internal leakage over time for the following reasons.

The presence of impurities increases friction between the ball and seat during valve operation, damaging or accelerating wear on the sealing surfaces.

Accumulation on the ball and sealing surfaces can cause imperfect sealing and minor internal leaks.

Impurities adhering to the ball or crystallization can affect the smoothness of the ball surface and even cause corrosion, leading to internal leaks.

Excessive and prolonged accumulation of solid residues can block the outlets for sealant grease, preventing the regular addition and replacement of lubricant. This leads to the solidification and degradation of the grease, further exacerbating the failure of the valve's seal.

4. Measures to reduce wastewater system failures

In response to the high failure rate of the current wastewater system, the following measures are proposed.

If the drain valve is pneumatic, the presence of impurities in the water can cause internal leaks in electric ball valves, largely dependent on the material of the sealing ring [4]. Therefore, research into sealing ring materials with good chemical stability, excellent sealing capabilities, and self-lubricating properties is advisable [5].

During regular operations, gas production stations need to further enhance the maintenance of electric ball valves. This can be done by greasing the valves through the greasing holes and cleaning the ball surfaces through the grease channels to remove debris from the sealing surfaces.

As the analysis shows, impurities in gas field water are key to the high failure rate of the wastewater system. Therefore, removing impurities from gas field water can reduce their adverse effects on equipment [6]. For example, filtration devices can be installed in front of devices like steam traps in the gas production station's wastewater system.

Depending on the water quality in gas fields, improvements to magnetic float level gauges can be made. For example, for issues with debris adhesion, changing the outer shell of the magnetic float to plastic and adding nano-coating to reduce debris adhesion. For issues with decreased magnetism due to debris adhesion, placing a magnetizing area around the float enhances its magnetism and reduces the frequency of failure. For issues with the hollow structure of the float becoming damaged and losing buoyancy, fill the inside of the float with foam to prevent water ingress and failure when the outer shell cracks. The technical parameters of the improved magnetic floats are shown in **Table 1**.

Table 1. Technical parameters of the improved magnetic floats

Parameter name	Parameter value
Material	Magnetic float: FRPP (fiber-reinforced polypropylene plastic) Outer coating: Nano-coating
Float diameter	φ40, φ43, φ45, φ50
Liquid density	0.45~2 g/cm^3
Liquid viscosity	≤0.05 Pa·S
Pressure	≤8 MPa
Temperature	Normal to 80℃

The improved magnetic floats have a full range of specifications, allowing for perfect matching with the properties, conditions, and density of the measured liquid. The density of the measured liquid can be as low as 0.45 g/cm^3, covering most liquid media and measurement conditions. The improved magnetic floats are manufactured using mature techniques, offer stable performance, and are suitable for use in environments with corrosive media and higher pressures.

5. Summary

Through the investigation of the operation of wastewater systems at 56 production stations, it was found that the main causes of magnetic float failures are debris adhesion and damage to the float itself, while the primary reasons for drain valve failures are operational difficulties and internal leaks. Based on the analysis of the causes of failures in the wastewater system, several measures have been proposed. These include optimizing the material of the sealing rings in pneumatic drain valves, enhancing regular maintenance of these valves, installing filtration devices in front of devices like steam traps in the natural gas production station's wastewater system, and improving the structure of the magnetic floats.

Disclosure statement

The authors declare no conflict of interest.

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