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METHOD OF WASHING WITH LIQUID IN CHEMICAL INDUSTRY, ELECTROSTATIC PRECIPITATORS CALCULATION

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Abstract. The main objective of this study is to develop and implement an optimized liquid washing method and an accurate electrostatic precipitator calculation framework for gas purification processes in the chemical industry, particularly in acetylene production systems. The proposed methodology aims to enhance process efficiency, reliability, and environmental safety by applying advanced analytical and control techniques. The research integrates modern process control strategies with smart diagnostics and monitoring tools, including the Plant Resource Manager (PRM), to ensure continuous operation and predictive maintenance. Through the application of PRM-based monitoring, operators can evaluate equipment conditions in real time, configure device parameters remotely, and minimize downtime. The study further focuses on mathematical modeling of electrostatic precipitators, analyzing their structural configuration, electric field parameters, and purification efficiency under varying operating conditions. By combining process optimization, data-driven decision-making, and intelligent control, the proposed approach contributes to improving gas-cleaning performance and achieving sustainable operation in chemical manufacturing systems.

Keywords: liquid washing method, electrostatic precipitator, gas purification, acetylene production, process optimization, mathematical modeling, PRM system, predictive maintenance, intelligent control, environmental safety.

Аннотация. Основной целью настоящего исследования является разработка и внедрение усовершенствованного метода жидкостной очистки и точной расчетной модели электростатического осадителя, предназначенных для процессов газоочистки в химической промышленности, в частности в системах производства ацетилена. Предлагаемый подход направлен на повышение эффективности технологических процессов, надежности оборудования и уровня экологической безопасности за счёт применения современных аналитических методов и средств автоматического управления. В работе реализована интеграция современных стратегий управления процессами с интеллектуальными системами диагностики и мониторинга, включая платформу Plant Resource Manager (PRM). Использование PRM позволяет операторам в реальном времени контролировать состояние оборудования, выполнять удалённую настройку параметров устройств и снижать время простоев за счёт предиктивного обслуживания. Особое внимание уделено математическому моделированию электростатических осадителей, анализу их конструктивных особенностей, характеристик электрического поля и эффективности газоочистки при различных эксплуатационных режимах. Объединение методов оптимизации процессов, принятия решений на основе данных и интеллектуального управления способствует повышению эффективности очистки газов и обеспечивает устойчивую работу технологических систем химического производства.

Ключевые слова: метод жидкостной очистки, электростатический осадитель, газоочистка, производство ацетилена, оптимизация процессов, математическое моделирование, система PRM, предиктивное обслуживание, интеллектуальное управление, экологическая безопасность.

Annotatsiya. Ushbu tadqiqotning asosiy maqsadi kimyo sanoatidagi gazlarni tozalash jarayonlari, xususan, atsetilen ishlab chiqarish tizimlari uchun moʻljallangan suyuqlik bilan yuvish usuli va elektrostatik choʻktiruvchi qurilmaning aniq matematik modelini ishlab chiqish va amaliyotga joriy etishdan iborat. Taklif etilayotgan yondashuv zamonaviy analitik usullar va avtomatik boshqaruv vositalarini qoʻllash orqali texnologik jarayonlarning samaradorligini, uskunalarning ishonchliligini hamda ekologik xavfsizlik darajasini oshirishga qaratilgan.Tadqiqotda Plant Resource Manager (PRM) platformasini oʻz ichiga olgan zamonaviy jarayonlarni boshqarish strategiyalari intellektual diagnostika va monitoring tizimlari bilan integratsiyalashgan. PRM tizimidan foydalanish operatorlarga uskuna holatini real vaqt rejimida nazorat qilish, qurilmalar parametrlarini masofadan sozlash va oldindan texnik xizmat koʻrsatish orqali ishdan chiqish vaqtlarini kamaytirish imkonini beradi.Shuningdek, elektrostatik choʻktiruvchi qurilmalarning matematik modellashtirilishi, ularning konstruktiv xususiyatlari, elektr maydoni parametrlari va turli ish rejimlaridagi gaz tozalash samaradorligini tahlil qilishga alohida e'tibor qaratilgan. Jarayonlarni optimallashtirish, ma'lumotlarga asoslangan qarorlar qabul qilish va intellektual boshqaruv usullarini uygʻunlashtirish gazlarni tozalash samaradorligini oshirishga hamda kimyoviy ishlab chiqarish tizimlarining barqaror ishlashini ta'minlashga xizmat qiladi.

Kalit soʻzlar: suyuqlik bilan yuvish usuli, elektrostatik choʻktiruvchi qurilma, gazlarni tozalash, atsetilen ishlab chiqarish, jarayonni optimallashtirish, matematik modellashtirish, PRM tizimi, oldindan texnik xizmat koʻrsatish, intellektual boshqaruv, ekologik xavfsizlik.

Introduction

Efficiency, sustainability, and accuracy are top considerations in process design and control in contemporary chemical businesses. Washing gases with liquid and then purifying them with electrostatic precipitators is one of the most important processes in gas treatment systems. These technologies are essential for lowering harmful pollutants and dust, which enhances production plants' environmental performance. The chemical industry relies heavily on acetylene as a feedstock for the production of several goods, including synthetic rubbers, solvents, and polyvinyl chloride (PVC). The term "foundation of the organic synthesis industry" is frequently used to describe it because of its industrial significance and diversity. The main source of industrial acetylene is calcium carbide (CaC_2), which necessitates very high temperatures (over 2000 °C) and a substantial energy input (464.6 kJ/mol). Following the formation of calcium carbide, acetylene gas is produced when it reacts with water. CaC_2 is synthesised using two primary technologies: the electro-thermal manufacturing method (ETMP) and the oxygen-thermal manufacturing process (OTMP). Despite being the most extensively used technique globally, ETMP is linked to significant greenhouse gas emissions and high energy usage. Consequently, enhancing process effectiveness and lowering energy losses in acetylene production systems continue to be crucial research goals. In order to improve gas-cleaning efficiency, lower energy consumption, and guarantee environmental compliance in the manufacturing of acetylene, this study focusses on optimising liquid gas-washing operations and electrostatic precipitator calculations [1].

Method

Chemical industries rely on a diverse range of feedstocks to produce petrochemicals, biofuels, food, microelectronics, textiles, and pharmaceuticals. Yet, due to their broad use, limited environmental consciousness, and the absence of effective sustainable engineering practices, they contribute notably to environmental degradation. This study seeks to develop a systematic framework for enhancing and managing chemical process systems, ensuring they function under optimal conditions. The goal is to strike a balance between efficiency, environmental responsibility, economic feasibility, and energy usage. The methodology centers on process optimization and advanced control strategies tailored for chemical systems [3]. Data analytics the evolution of sensors and monitoring systems in manufacturing has enhanced real-time data collection, enabling operators to implement necessary adjustments. Despite the vast amounts of data generated, the industry still struggles with a lack of manufacturing Intelligence (MI). Data analytics is essential for converting raw data from sensors and monitoring systems into actionable manufacturing intelligence. These analytical techniques are categorized into three main types:

Descriptive analytics: Used to evaluate how well the gas-washing and electrostatic precipitation systems are currently functioning. It gives engineers up-to-date information on process factors like dust concentration, pressure, and gas temperature.

Using both historical and current data, predictive analytics is used to forecast equipment performance and possible deviations. Using PRM's diagnostic capabilities, this method facilitates early fault diagnosis and preventive maintenance.

Prescriptive analytics: This technique uses optimisation algorithms to suggest control measures, including modifying the electrostatic field voltage or the flow rate of washing liquid, to preserve the best possible gas purification efficiency [4].

All three forms of analytics must be used in tandem for manufacturing to achieve smart operations. Prescriptive intelligence has historically depended on highly qualified experts. But because to developments in machine learning, deep learning, optimisation, and big data analytics, computers may now provide prescriptive intelligence, increasing system autonomy.

Command The theories and algorithms pertaining to model-based control and optimisation in manufacturing companies are the main focus of this section. Automated process management combined with digital control systems improves operational effectiveness, maximises energy use, and guarantees enterprise-wide security. Additionally, system-wide algorithms may concurrently manage manufacturing components thanks to cloud infrastructure, bringing operations into line with consumer requests.

Plant Resource Manager (PRM). PRM can provide answers for specific issues.

1. Monitor equipment status in real time and operate remotely. The equipment can be commissioned quickly due to the device type manager (DTM) and other specific calibration tools. By remotely tracking and adjusting device parameters, labour hours can be decreased.

2. Assess device and equipment performance. Regular and automated status reports provide extensive data about the condition of the equipment and a complete evaluation of the overall health of the plant.

3. Provide information to enhance maintenance and operation; critical equipment data can be immediately confirmed.

The PRM interface allows for remote configuration and modification of equipment parameters. Through user-friendly graphical interfaces customised for each model, the vendor-provided DTM application allows users to quickly and graphically modify device parameters. A specialised PRM plug-in application enables efficient and efficient valve tuning for more complicated devices, such as valve positioners. These tools increase the overall effectiveness of maintenance procedures and reduce device downtime [5].

Tube electrostatic precipitators. Dust and flue gases are transferred to the bottom of the device under a perforated grid with fixed electrodes and distributed among the tubular electrode anodes. Electrodes-cathodes, forming a “crown”, are installed inside the tubular electrodes. The electrodes are fixed on a common frame supported by an insulator. Under the influence of an electric field, particles contained in the gas settle. The particles that settle on the anode and form a layer are periodically shaken and collected in a conical bottom at the bottom of the device. Typically, the tubes are made with a diameter of 150-300 mm and a length of 3-4 m. The diameter of the wires pulled inside the tubes is 1.5-2.0 mm. The degree of purification of gases is 99%, in some cases 99.9% [6].

In plate electrostatic precipitators, the anode is performed by the plates, and the cathode by the wires stretched between the plates. The degree of gas purification in electrostatic precipitators depends on the electrical conductivity of the dust. When the concentration of particles in the gas is high, additional gas filters are installed before the electrostatic precipitator to reduce the concentration of particles. Dust buildup on the electrodes of a plate electrostatic precipitator is easier to clean compared to a tubular filter and requires less energy per unit of wire length. Furthermore, these filters are more compact, use less metal, and are simple to assemble.

When the number of electrodes and the cross-sectional area of the device are known, the calculation for electrostatic precipitators involves determining the length of its "crown" electrode. The current in the electrostatic precipitator is given by the formula I="iL", where "I" is the current density and "L" is the length of the electrode [7].

The critical potential gradient is determined using the following equation

$$E_{kr} = 31 + 9.54\sqrt{\frac{\sigma}{r}}$$

Here, "σ" represents the ratio of the air density under specific conditions at a pressure of 0.1 MPa to the density at a temperature of 25°C and a pressure of 10 Pa. By knowing the distance between the electrodes, the potential difference across them can be calculated.

The degree of gas purification can be determined using the following general formula:

$$\eta_e = 1 - \frac{x_2}{x_1} = 1 - e^{-\omega f}$$

Here, x_1 and x_2 represent the concentrations of solid particles in the gas entering and leaving the electrostatic precipitator, measured in kg/m³. e is the velocity of the charged particles moving toward the electrode surface, measured in m/c. f is the specific settling surface, measured in m²/(m³s).

For tubular electrostatic precipitators

$$f = \frac{2l}{rw}$$

For plate electrostatic precipitators:

$$f = \frac{2l}{hw}$$

where, "l" represents the length of the tube or plate in meters m; "r" is the radius of the deposition electrode tube in meters m; "h" is the distance between the deposition and "crown" electrodes in meters "m" and "w" is the gas velocity within the electrostatic precipitators in meters per second (m/s).

The power "p" (kW) of the lifting and discharging unit that supplies current to the electrostatic precipitators is determined by the following formula.

$$P = \frac{0.707 * 10^5 VIm + 0.5}{\eta}$$

where "V" is the difference in working potentials at the electrodes, kV; "m" 1.5….2.2 is the shape coefficient of the rectified current curve; η = 0.7…0.8 is the aggregate [8].

Electric filter calculation

Initial data. The irradiating electrode diametric $D_1 = 2.5 * 10^{-3} m$, the distance between them $d = 0.24m$ and their active length $l_1 = 924m$, then we calculate the degree of gas purification in a horizontal plate electric filter with a cross-sectional area $F = 7.5m^2$. The total area of the working surface of the electric filter $S = 242m^2$ the number of collecting electrodes $N = 16$, the distance between the collecting and irradiating electrode planes $H = 0.15m$. The total length of the electric field $L = 4.8m$, the average voltage $U_o = 46kv$.

The gas containing solid particles in the amount of $z_1 = 40\, g/m^3$ enters the electrostatic precipitator. The gas contains the following components; 13% 13% $CO_2, 6.5\% \ O_2, 8.5\% \ N_2O, va\ 72\% \ N_2$. The pressure in the system is$p_2 = 200\ kg * k/m^2$ and the temperature of the gas is $t_g = 150C$

The composition of solid particles is given below: r = radius, Φ_i = particles

1-table.

r, mm	0.5	2.5	5.0	10	15	20	25
Φ_i %	5.0	10.0	10.0	15.0	20	20	20

Solution relative density of gas flow

$$\beta = \frac{B \pm P_g}{1.03 * 10^4} * \frac{293}{t_g + 273} = \frac{1.03 * 10^4 - 2 * 10^2}{1.03 * 10^4} * \frac{293}{(150 + 293)} = 0.68$$

Critical electric field voltage:

$$E_o = 3.04\left(\beta + 0.0311\sqrt{\frac{2\beta}{D_1}}\right)10^6 = 3.04\left(0.68 + 0.0311\sqrt{\frac{2 * 0.68}{25 * 10^{-3}}}\right)10^6 = 4.26 * 10^6\, B/m$$

Critical voltage of the irradiating electrode:

$$U_o = E_o\frac{D_1}{2}\left(\frac{\pi H}{d} - \ln\frac{\pi D_1}{d}\right) = 4.26 * 10^6\,\frac{2.5 * 10^{-3}}{2} * \left(\frac{3.14 * 0.15}{0.24} - \ln\frac{3.14 * 2.5 * 10^{-3}}{0.24}\right)$$
$$= 28.5 * 10^{-3} B$$

$$\frac{H}{d} = \frac{0.15}{0.24} = 0.625$$

When $R_o = 2.1 * 10^{-4}\ m^2/(V * s)$ and $\nu = 7.7 * 10^{-2}$, we determine the linear density of the radiation as follows:

$$i_o = \frac{4\pi^2 R\nu U}{d^2 * 9 * 10^9\left(\frac{\pi H}{d} - \ln\frac{\pi D_1}{d}\right)}(U - U_o)$$
$$= \frac{4 * 3.14^2 * 2.1 * 10^{-4} 7.7 * 10^{-2} * 46 * 10^3}{0.24^2 * 9 * 10^9\left(\frac{3.14 * 0.15}{0.24} - \ln\frac{3.14 * 2.5 * 10^{-3}}{0.24}\right)} * (46 * 10^3 - 28{,}5 * 10^3)$$
$$= 0.185 * 10^{-3}\, A/m$$

The values of the dynamic viscosity of the gas flow under standard conditions and the constant S are given in Table 1

In this case:

$$\mu_{CO_2} = 13.7 * 10^{-6} * \frac{273 + 254}{423 + 254}\left(\frac{423}{273}\right)^{\frac{3}{2}} = 0.22 * 10^{-4}\, kg/(ms)$$

$$\mu_{O_2} = 20.3 * 10^{-6} * \frac{273 + 254}{423 + 131}\left(\frac{423}{273}\right)^{\frac{3}{2}} = 0.27 * 10^{-4}\, kg/(ms)$$

$$\mu_{H_2O} = 9.0 * 10^{-6} * \frac{273 + 673}{423 + 673}\left(\frac{423}{273}\right)^{\frac{3}{2}} = 0.149 * 10^{-4}\, kg/(ms)$$

$$\mu_{N_2} = 17.0 * 10^{-6} * \frac{273 + 114}{423 + 114}\left(\frac{423}{273}\right)^{\frac{3}{2}} = 0.231 * 10^{-4}\, kg/(ms)$$

2-table

Gas	$\mu_0 \ * 10^7 kgk\,s/m^2$	S
Nitrogen	17.0	114
Air	17.5	124
Water vapor	90	673
Sulfur dioxide	11.7	396
Carbon dioxide	13.7	254
Oxygen	20.3	131
Carbon monoxide	16.6	100

The relative molecular mass of a gas stream is determined by the amount of a and the molecular mass of the components [9].

$$M = a_{CO_2} * M_{CO_2} + a_{O_2} * M_{O_2} + a_{H_2} * M_{H_2O} + a_{N_2} * M_{N_2} =$$
$$= 0.13 * 44 + 0.065 * 32 + 0.085 * 18 + 0.72 * 28 = 29.35$$

We calculate according to above formula.

$$\frac{M}{\mu}=\frac{a_{CO_2}*M_{CO_2}}{\mu_{CO_2}}+\frac{a_{O_2}*M_{O_2}+a_{H_2}}{\mu_{O_2}}+\frac{a_{H_2}*M_{H_2O}}{\mu_{H_2O}}+\frac{a_{N_2}*M_{N_2}}{\mu_{N_2}}$$
$$=\frac{0.13*44}{0.22*10^{-4}}+\frac{0.065*32}{0.27*10^{-4}}+\frac{0.085*18}{0.149*10^{-4}}+\frac{0.72*28}{0.231*10^{-4}}=130.9*10^{4}\frac{kg}{kmol}$$

Dynamic viscosity of gas flow:

$$\mu=\frac{M}{130.4*10^{4}}=\frac{29{,}35}{130.9*10^{4}}=0{,}225*10^{-4}\,kg/(ms)$$

We determine the scattering rate of particles of different diameters onto the deposition electrode from the formula below:

If $1\le r\le 2.5mkm,\ \ w_p=\frac{0.118*10^{-11}*E^2*g}{\mu}r$

If $0.05\le r\le 1mkm,\ w_p=\frac{0.118*10^{-11}*E^2*g}{\mu}r\left(1+\frac{A_s}{r}\right)$

$w_{p1}=1.25*10^{-2}\,m/s$
$w_{p2}=35.2*10^{-2}\,m/s$
$w_{p3}=10.4*10^{-2}\,m/s$
$w_{p4}=20.8*10^{-2}\,m/s$
$w_{p5}=31.2*10^{-2}\,m/s$
$w_{p6}=41.6*10^{-2}\,m/s$
$w_{p7}=52.0*10^{-2}\,m/s$

Relative surface area of sediment

$$f=\frac{S}{F*w_G}=\frac{242}{0.8*7.5}=40.5\frac{m^2}{m^3/s}$$

The actual speed of particle scattering in the electric field of the electrostatic precipitator is 2 times less than the theoretically calculated one, therefore, we reduce the degree of the formula for calculating the gas purity threshold by 2 times [10].

$$\frac{f*w_{n1}}{2}=\frac{40.5*1.25*10^{-2}}{2}=0.253$$

For large particles, this value is 1.055; 2.100; 4.220; 6.320; 8.430; 10.540, respectively. In this case, the degree of purity of the gas is as follows:

$$\eta_{\Phi}=1-e^{-wf}=1-e^{-0.253}=22\%$$

For particles of other sizes, this value is 65; 87.8; 98.6; 99.8; 99.98; 99.99%, respectively. The overall degree of gas purification in the electrostatic precipitator:

$$\eta=\frac{\eta_{\Phi1}\Phi_1}{100}+\frac{\eta_{\Phi2}\Phi_2}{100}+\frac{\eta_{\Phi3}\Phi_3}{100}+\frac{\eta_{\Phi4}\Phi_4}{100}+\frac{\eta_{\Phi5}\Phi_5}{100}+\frac{\eta_{\Phi6}\Phi_6}{100}+\frac{\eta_{\Phi7}\Phi_7}{100}$$
$$=\frac{22*5}{100}+\frac{65*10}{100}+\frac{87.8*10}{100}+\frac{98.6*15}{100}+\frac{99.8*20}{100}+\frac{99.98*20}{100}$$
$$+\frac{99.99*20}{100}\approx 93.1\%$$

Discussion

Understanding the conditions under which the process functions is essential to simulating the behaviour of the roaster off-gas system. Complete knowledge of all pertinent variables, such as beginning circumstances, inputs, outputs, and system states, is necessary for creating an accurate model. The physical characteristics of the system, such as the volume of the various compartments, the cross-sectional areas of the pipes, and the distances between different elements, can provide some of this information directly. While some data points may need the use of process modelling or system identification techniques, other data points are dependent on operational factors [11].

3-table.

Operating Parameters of Inlet and Outlet Streams in the Separator

	Input	output
pyrolysis gas	87°C 8 kPa	35°C
cold water	5°C 0.4-0.5MPa	10°C 0.15-0.25 MPa
25% ethylene glycol circulating coolant	-2°C 0.4-0.5MPa	3°C 0.15-0.25 MPa
low pressure superheated steam	300°C 1.6MPa	

The temperature of the pyrolysis gas leaving the acetylene furnace and saturated with steam is 87 °C and the pressure is 8 kPa. It enters the lower part of the cooling column and is cooled by the soot water that is sprayed directly and comes from the hyperbolic column. The pyrolysis gas passes from bottom to top through the cooling column and, after cooling to 60 °C, exits from the upper part of the lower part of the cooling column to the electrofilter, where the soot is separated again. A small amount of demineralized water is sprayed onto the upper part of the electrofilter. Then the soot in the gas stream between the two electrodes is captured by small negatively charged water droplets, and the soot particles surrounded by ionized water are deposited on the electrode plate as a precipitate, which is then continuously washed with a water film. After washing, the slag water is discharged from the bottom, and the pyrolysis gas, after separation from the dust, is returned to the upper part of the cooling column [12]. The upper and lower parts of the cooling column are surrounded by a waterproof hermetic barrier. Most of the cooling water used comes from the slag water circulation system, this pyrolysis gas water is supplied to the upper and lower parts of the cooling column. Demineralized water is supplied to the upper part of the column for final cooling and washing, and the washed pyrolysis gas at 35°C enters the compression process. The flow of the three streams is demineralized and the supply of cooling water to the pyrolysis gas cooling column is controlled by a control valve. In order to prevent damage, leakage and cracking of the electrostatic precipitator shell due to steam condensation in the high-voltage insulation cabinet, water vapor with a temperature of 165°C is supplied to the “jacket” part of the electrostatic precipitator shell. Nitrogen is continuously supplied to the wire at the top of the insulators to prevent the ingress of outside air and the formation of an explosive gas-air mixture. During start-up, to prevent the accumulation of soot (slag) on the insulators, to prevent current leakage from the bottom of the insulating sleeve, and to ventilate the insulator with natural gas at a temperature of 100°C [13].

The outlet pipe of the electrostatic precipitator has an automatic oxygen analyzer that controls the oxygen content in the pyrolysis gas. When the oxygen content exceeds the upper limit, the high-voltage power supply of the electrostatic precipitator is automatically turned off, and the oxidative pyrolysis line is turned off as a result of blocking.

At the same time, the electrostatic precipitator has two explosion-proof discs that burst when the pressure exceeds 0.12 MPa and release the pressure into the air

Results

The electrostatic precipitation system used in the acetylene production process demonstrated a high purification efficiency, with measured values ranging from 98.6% to 99.99%, depending on the particle size. Larger particles (≥10 mm) showed near-total removal efficiency, confirming the effectiveness of the electrostatic separation process under optimized operating conditions.

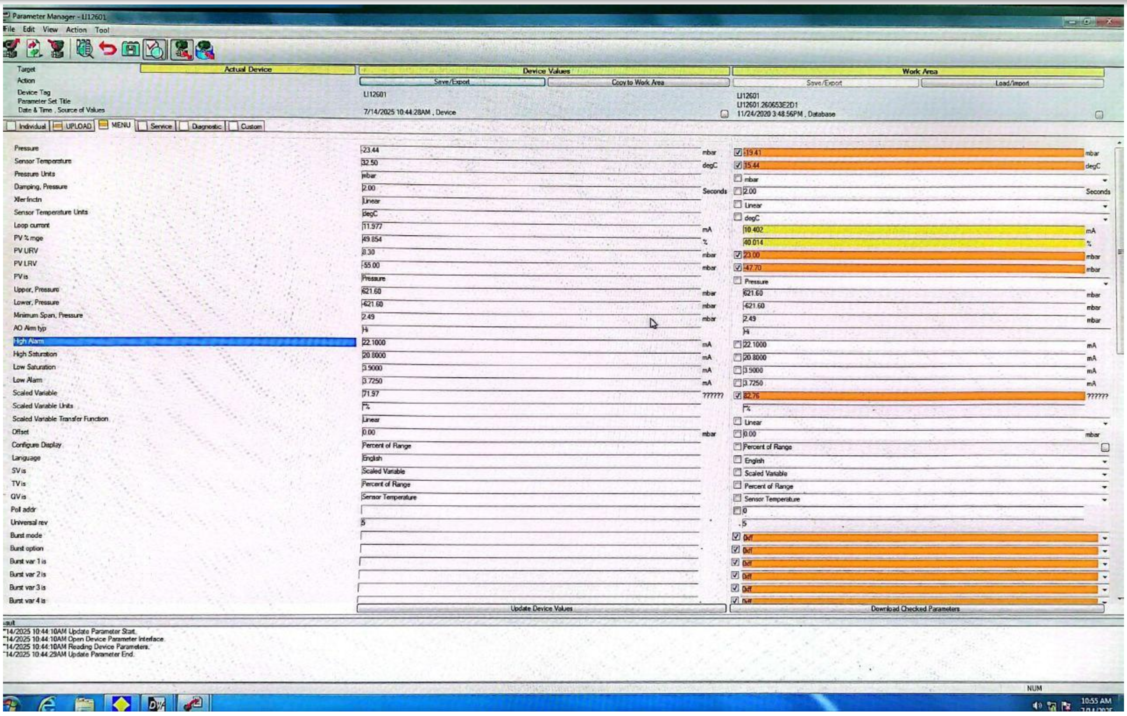

Fig.1 presents the Plant Resource Manager (PRM) interface.

It provides real-time data monitoring and device diagnostics. It displays alarm conditions, patrol intervals, and flow parameters across the network. Operators can remotely configure or troubleshoot systems, significantly improving operational uptime and reducing manual labor. The integration of PRM into the acetylene production system ensures rapid fault detection, predictive maintenance, and better process control

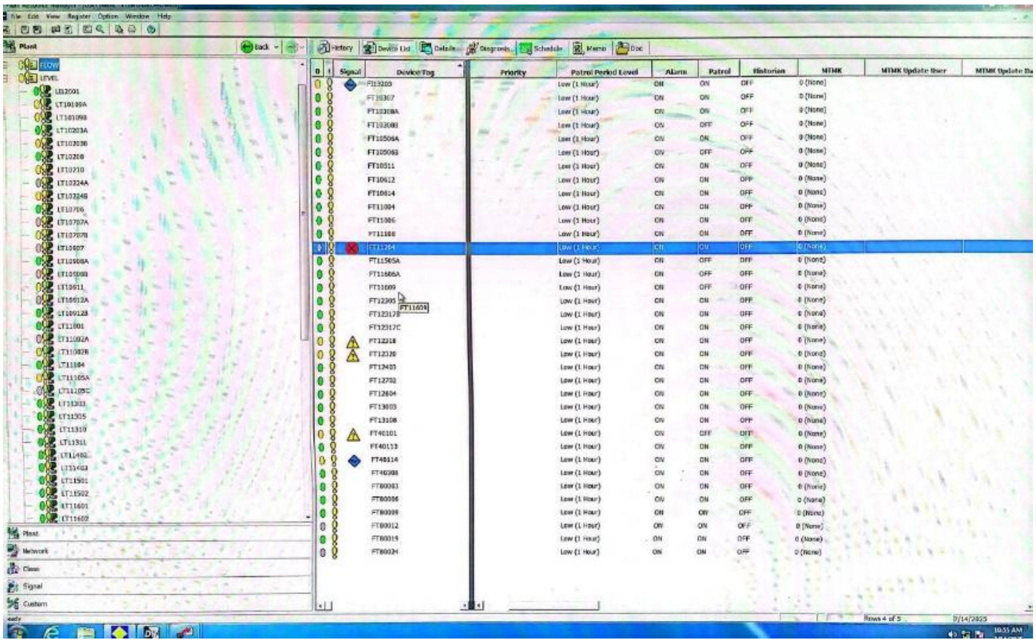

Fig .2 Pressure sensor device LI12601.

On July 14, 2025, diagnostic work was carried out on the pressure sensor device LI12601 using the Parameter Manager interface. The device data was retrieved, configured, and verified successfully.

The actual pressure reading from the sensor was 621.60 mbar, while the measured sensor temperature was 23.4°C. The output signal from the sensor loop was 22.10 mA, indicating that the transmitter was operating near its upper calibrated limit. The scaling mode was set to linear, and the process variable (PV) was represented as a percentage of range, confirming proper configuration for continuous monitoring [14].

The device's burst mode and polling address parameters were also accessible, suggesting that the sensor supports digital communication, most likely via HART protocol. The configuration log shows that the process of opening the device, reading parameters, and updating configuration settings was completed between 10:44:10 AM and 10:44:29 AM on the same day.

The consistency between the sensor's physical readings and the configured limits confirms that the device was functioning properly and transmitting accurate data to the control system. These results play an important role in maintaining process stability and control accuracy in the acetylene gas-washing system.

The experimental analysis also indicated that proper temperature control (via cooling towers and demineralized water spray) combined with precise electrostatic field application enables reliable and repeatable performance under varying loads. The gas was successfully cooled from 87°C to 35°C, and soot was continuously removed using ionized water droplets, ensuring a clean gas stream for compression.

These results confirm that an integrated approach involving smart diagnostics (PRM), efficient mechanical design (injector blocks), and optimized separation (electrostatic filters) can significantly enhance reliability, energy efficiency, and environmental safety in industrial gas treatment processes

Conclusion

Enhancing operational reliability and process safety has been shown to be possible through the incorporation of the PRM system into the acetylene manufacturing process. Predictive maintenance scheduling, remote field device configuration, and early abnormal condition detection are all made possible by PRM's sophisticated diagnostic and monitoring features. These characteristics increase the overall effectiveness of gas-washing and electrostatic precipitation systems and decrease unscheduled downtime.

The use of mathematical calculations and equipment analyses in the production process improves operational reliability as well as helps in anticipating unexpected problems.

In order to guarantee long-term durability and reliable performance, the study also highlights how crucial it is to take working conditions such as temperature, load, and medium composition into account when designing equipment and choosing materials.

Furthermore, accurate process parameter monitoring and prompt management interventions are essential to preserving the dependability of technological equipment. Variations in voltage, pressure, or flow rate can have a major impact on system performance and possibly result in component failures. Thus, maintaining ideal operating conditions through the use of PRM-based monitoring and automated control techniques ensures both environmental safety and production continuity.

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