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Mapping Characteristics of the Filtration Performance of Gas Turbine Inlet Air Filters under Typical Environmental Conditions

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Received: 26 March 2026; Accepted: 14 May 2026; Published: 12 July 2026

ABSTRACT: The performance evaluation of gas turbine inlet air filtration systems is commonly based on standardized laboratory testing; however, discrepancies frequently arise between laboratory results and actual operating performance. In this study, an on-site testing apparatus was developed to investigate filtration behavior under realistic operating conditions. Field measurements were conducted to analyze pressure loss evolution, particle-size-dependent filtration efficiency, and the influence of environmental parameters, including temperature, humidity, and ambient particulate concentration. Results show that filter pressure loss increased progressively with operational loading, while short-term fluctuations were associated with variations in environmental conditions. Filtration efficiency exhibited an overall increasing tendency with particle size, with minor fluctuations observed at larger particle sizes, and showed limited dependence on pressure loss within the investigated operating range. Correlation analysis indicated that ambient temperature showed a stronger relationship with filtration efficiency compared with humidity and differential pressure, suggesting that environmental conditions play an important role in practical filtration performance. To evaluate the consistency between laboratory certification and field operation, comparative tests were carried out at three representative gas turbine power plants operating under different environmental conditions. Although laboratory and field results demonstrated similar efficiency trends, noticeable quantitative deviations were observed. Correction factors relating laboratory-tested efficiency to field-measured efficiency were determined as 0.82, 0.86, and 0.54 for the three sites, respectively. The proposed correction-coefficient approach provides a practical method for translating standardized laboratory performance into realistic operational evaluation, offering useful guidance for filter selection, performance assessment, and operational management of gas turbine inlet air filtration systems.

KEYWORDS: Filtration performance; gas turbine; inlet air filter; laboratory test; typical environmental conditions

1 Introduction

The health assessment of gas turbine inlet air filtration systems is crucial to the overall operational efficiency and reliability of the unit. The inlet air quality directly affects compressor fouling, power output degradation, and maintenance intervals during long-term operation [1,2]. At present, the performance evaluation of inlet air filters primarily relies on laboratory test results. Under controlled laboratory conditions, with standardized boundary parameters such as temperature, humidity, particulate matter composition, particle size, and air volume, filter performance can be quantified with relative convenience. However, practical operating environments differ significantly from ideal laboratory conditions, resulting in substantial uncertainty in the prediction of actual filtration performance [3–5].

In actual operational scenarios, the inlet air volume of a gas turbine fluctuates dynamically, making it challenging to maintain a constant specific operating condition. The air volume directly determines the filter surface flow velocity, thereby significantly influencing its filtration efficiency and resistance characteristics. Furthermore, the atmospheric environment in which the filter operates is in a state of constant change. Parameters such as temperature and humidity have notable impacts on filtration performance, while variations in the concentration and particle size distribution of atmospheric particulate matter introduce additional uncertainties [6,7]. Consequently, discrepancies frequently arise between laboratory test results and actual field performance.

To improve evaluation consistency, researchers and equipment manufacturers have developed standardized laboratory testing methodologies for air filters. However, China has not yet established a nationally unified standard system specifically tailored for gas turbine inlet air filtration. Although several association standards, including Test Testing Apparatus of Gas Turbine Inlet Air Filter (T/CAQI 247-2022) [8], were released in 2022, these documents are currently limited to industry or organizational applications and have not yet formed a comprehensive national standard framework. There remains a lack of systematic specifications concerning on-site testing procedures, cleanliness control requirements, and performance management practices for gas turbine air intake filtration systems. Consequently, manufacturers of main engines and air intake equipment frequently resort to referencing standards for general ventilation filters, such as Chinese national standard GB/T14295-2019 [9]. Internationally, the selection, configuration, testing, and evaluation of gas turbine air intake filtration systems include the ASHRAE52.2-2017 standard formulated by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, the European standard EN779-2012, and the international standard ISO16890-2016 [10–12]. These standards employ largely similar testing apparatuses and procedures in laboratory settings, enabling effective assessment of key performance indicators of air filter cartridges, including filtration efficiency, pressure drop, and dust holding capacity. Nevertheless, owing to their general applicability, these standards are not specifically tailored to the unique characteristics of gas turbines and thus fail to meet on-site operational requirements. In addition, testing methods and environmental assumptions embedded in foreign standards are largely based on European and American atmospheric conditions, which differ significantly from those encountered in China [13].

Building upon existing standard-based evaluation frameworks, recent research has increasingly focused on assessing the performance of gas turbine inlet air filtration systems under realistic operating conditions [14]. Effiom et al. [15] conducted wind tunnel experiments under simulated offshore conditions and reported substantial variation in particle removal efficiency among different filter grades under realistic particulate loading. Their results indicated that standardized efficiency classifications may not fully represent filtration performance under practical operating environments, highlighting limitations of laboratory-based evaluation approaches. Fauzi and Sulaiman [16] analyzed operational data from a GE 9HA.02 gas turbine and demonstrated that increases in inlet air filter pressure drop directly resulted in higher fuel consumption during plant operation, illustrating that filtration performance has measurable operational and economic impacts that cannot be fully captured by static laboratory evaluation indicators. Suman et al. [17] carried out field investigations on operating gas turbines and observed that fine particles could penetrate filtration systems despite meeting laboratory classification requirements, further indicating discrepancies between standardized testing results and actual protection effectiveness.

Despite these advances in both standardization and recent research efforts, existing studies have still primarily focused on controlled testing conditions. Systematic investigations addressing the relationship between environmental parameters and actual filtration performance under real operating conditions remain limited. In particular, a quantitative mapping between laboratory test results and field filtration performance under typical environmental conditions has not yet been fully established. This gap restricts

accurate prediction of filter performance and limits the effectiveness of filter selection and operational management strategies for gas turbine inlet systems.

To address this issue, this study conducts field performance testing of gas turbine inlet air filters under typical environmental conditions characterized by high humidity, elevated particulate concentration, and complex atmospheric variability. By integrating laboratory testing and on-site measurement systems, the dynamic response characteristics of filtration efficiency during real operation are investigated. Furthermore, a site-dependent correction framework linking laboratory test data with field performance is established, and a correction-coefficient method is proposed to construct a quantitative mapping relationship between laboratory measurements, environmental parameters, and actual filtration performance. The results aim to improve prediction accuracy of filter behavior under real operating conditions and provide a practical evaluation framework for performance prediction and optimization of gas turbine inlet air filtration systems.

2 Experimental Detection Devices

The laboratory testing apparatus is depicted in [Fig. 1a](#). The main improvement of this device, when compared to traditional testing platforms for air filters that comply with the national standard GB/T 14295-2019, is its significantly expanded testing capacity. While national and international standards stipulate a maximum test air volume of 3400 m³/h, this device can handle up to 5000 m³/h. The national standard specifies a dust concentration of 70 ± 7 mg/m³ for dust holding capacity tests, whereas the international standard ISO 16890-2016 sets it at 140 ± 14 mg/m³. In contrast, the specially engineered high-concentration dust generator in this device can continuously produce dust concentrations exceeding 1000 mg/m³, enabling the simulation of the dust holding performance of gas turbine air intake filters under desert conditions and extreme climates. Additionally, an aerosol generator has been incorporated, capable of dispersing particles down to a minimum size of 0.05 µm, thereby meeting the specified requirements. High-precision control ensures that measuring instruments such as pressure sensors and temperature and humidity sensors also adhere to the specified standards.



(a)

Figure 1: (Continued)

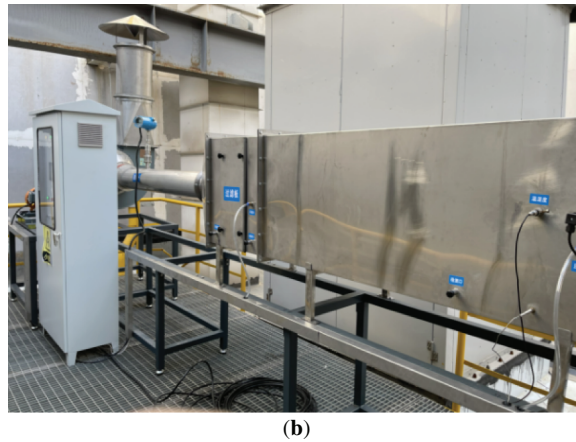


Figure 1: Physical images of the testing devices. (a) the laboratory testing device; (b) the on-site testing device.

The physical appearance of the on-site testing device is presented in Fig. 1b. The development of the on-site testing device focuses on structural design, testing content, and the fulfillment of other technical requirements. In terms of structural design, protective measures such as rain covers and bird screens are equipped according to the characteristics of the operating environment, to ensure that the device meets the strength and rigidity requirements under special working conditions. The testing mainly includes measuring the wind resistance of the filter and the filtration efficiency of particles with different sizes under different pressure drop conditions. The on-site testing of the device shows that the device operates normally, and key performance indicators (including parameters such as air flow rate and pressure loss) meet the design requirements. Verification tests show that the air flow rate measurement range of the device is 499.3–5001.8 m³/h, with a relative error of 0.86%; the relative error of pressure difference measurement is 0.39%, indicating that it has the function of evaluating the filtration performance of gas turbine intake filters under actual working conditions.

This study has also established a systematic experimental testing protocol, covering aspects such as device installation, flow control, data acquisition, and data analysis. Based on this protocol, a comprehensive testing plan has been devised, offering a standardized framework for the execution of experimental tests.

(1) Counting Efficiency Test

Once the filter installation is complete and the on-site testing apparatus has been successfully debugged and qualified, the testing process can commence. For particles within a specified size range (i.e., particles falling between two size thresholds), the counting efficiency E can be determined utilizing the following formula [11]:

$$E = (1 - n_i/N_i) * 100\%, \quad (1)$$

where:

n_i : Particle count for size fraction “ i ” located downstream of the filter,

N_i : Particle count for size fraction “ i ” upstream of the filter.

(2) Gravimetric Efficiency Test

The range between the initial resistance P_{ini} and the final resistance P_{fin} of the filter was divided into ten equal segments (this value is adjustable based on actual requirements). During the testing procedure, upon reaching a specific divided value P_i , the tested filter and the downstream backup filter should be removed

from the on-site testing apparatus. When disassembling the filters, utmost care should be taken to prevent the detachment of particulate matter from the filters. The filters were then weighed, and the gravimetric efficiency at resistance level P_i was calculated as [11]:

$$A_i = \frac{\Delta m_i}{\Delta m_i + \Delta M_i} * 100\%, \quad (2)$$

where:

Δm_i : The increased weight of the tested filter,

ΔM_i : The increased weight of the downstream backup filter.

Thus, ten gravimetric efficiency values corresponding to ten resistance levels were obtained as the test filter approached its terminal resistance.

3 Correlation Characteristics between Filtration Performance and Environmental Parameters

3.1 Field Filtration Performance Testing

Based on the on-site performance testing apparatus for the gas turbine inlet air filtration system, a gas-fired power plant in Hangzhou was chosen for the testing experiments. This apparatus enabled long-term monitoring of inlet air parameters. The tested filtration unit is a self-cleaning gas turbine inlet air filtration system composed of combined cylindrical and conical filter elements, which is a configuration widely adopted in industrial gas turbine intake systems. To investigate the patterns of filtration performance variation, the test air volume was consistently set at 2500 m³/h to streamline subsequent data analysis and processing. A total of 25 datasets were collected during the test with non-uniform sampling intervals. Analyses were carried out on the differential pressure variation of the inlet air filter, the filtration efficiency for particulate matter across different particle size ranges, and the correlation between filtration efficiency and atmospheric conditions. The findings are presented as follows.

(1) Filter Pressure Loss

The pressure loss variation of the filter throughout the testing process is depicted in Fig. 2. Under a constant test air volume, the filter pressure loss generally exhibits a linear increase, albeit with occasional decreases followed by subsequent increases. This suggests that the pressure loss variation of the filter during testing is primarily governed by the combined effects of external particulate matter concentration and atmospheric humidity. The influence of particulate matter concentration sustains an upward trend in the filter pressure loss, whereas variations in atmospheric humidity induce fluctuations in pressure loss within specific ranges.

(2) Filter Efficiency

The filtration efficiencies of the tested filter for different particle size ranges are presented in Fig. 3. Each subplot illustrates the variation in filtration efficiency along the sampling sequence under identical airflow conditions.

As shown in Fig. 3, the inlet air filter exhibits effective removal performance across all investigated particle sizes. The average filtration efficiencies for particles of increasing size are 73.00%, 76.40%, 78.20%, 83.08%, 87.09%, and 86.65%, respectively, indicating an overall increasing tendency of filtration efficiency with increasing particle diameter, although a slight fluctuation is observed in the largest particle size range. This behavior generally agrees with classical fibrous filtration theory, in which interception and inertial impaction mechanisms become increasingly dominant for larger particles, thereby enhancing particle capture probability.

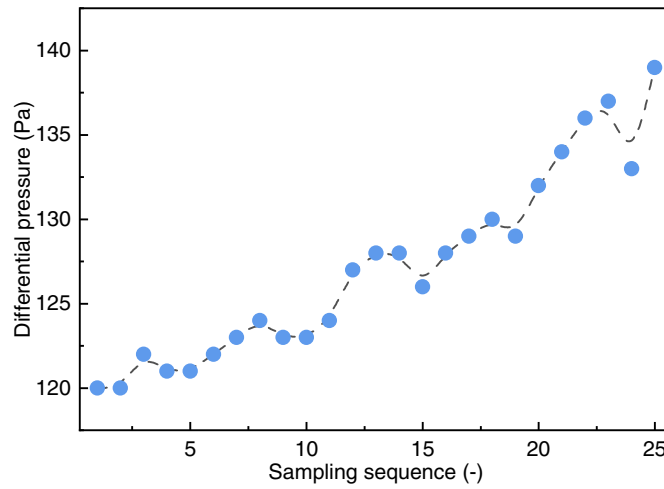


Figure 2: Variation of filter differential pressure with sampling sequence (25 sequential datasets).

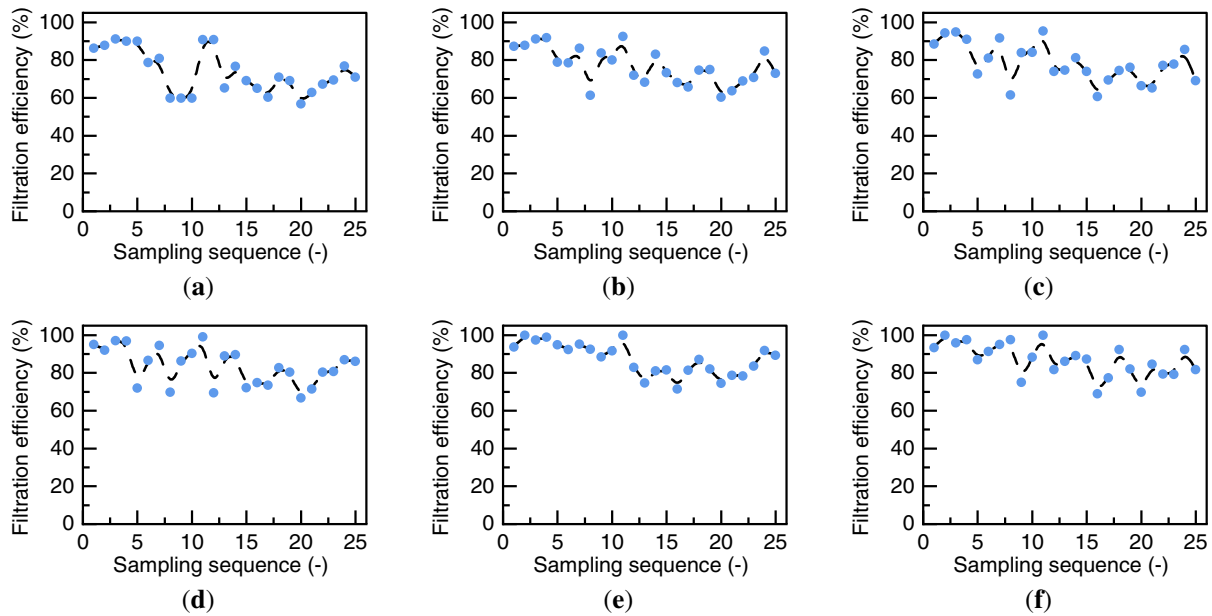


Figure 3: Filtration efficiency of the tested filter for different particle size ranges. (a) 0.3–0.5 μm ; (b) 0.5–1.0 μm ; (c) 1.0–2.5 μm ; (d) 2.5–5.0 μm ; (e) 5.0–10.0 μm ; (f) above 10.0 μm .

Despite the overall stable performance, noticeable fluctuations in filtration efficiency are observed throughout the sampling sequence. These variations indicate that filtration efficiency is influenced not only by filter loading but also by external environmental factors, such as ambient particulate concentration, relative humidity, and variations in particle properties.

As shown in Fig. 2, the filter differential pressure gradually increases during operation; however, Fig. 3 demonstrates that no evident enhancement in filtration efficiency occurs within the investigated pressure loss range. This indicates that particle accumulation primarily increases flow resistance rather than improving particle capture performance.

3.2 The Relationship between Filtration Efficiency and Environmental Parameters

To examine the influence of environmental conditions on filtration performance, the filtration efficiencies for two representative particle size ranges, 0.3–0.5 μm and 2.5–5.0 μm , were analyzed together with atmospheric temperature, relative humidity, filter differential pressure, and ambient particulate matter concentration, as illustrated in Fig. 4. The solid and dashed black lines in Fig. 4 correspond to the filtration efficiency data for these two particle size ranges, derived from Fig. 3a,d, respectively, and are used here to facilitate comparison between filtration performance and environmental variations.

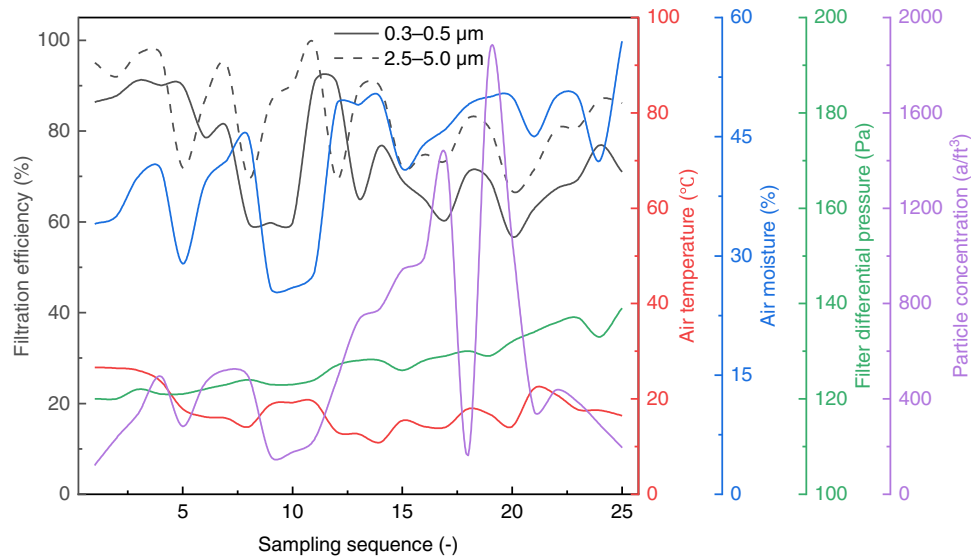


Figure 4: Relationship between filtration efficiency and environmental parameters.

The results show that filtration efficiencies in both particle size ranges fluctuate throughout the monitoring period, indicating that filter performance varies under changing environmental conditions. No substantial difference in fluctuation magnitude is observed between the two size ranges, suggesting that environmental factors affect particle removal across multiple capture mechanisms. Variations in relative humidity, temperature, and particle concentration appear to coincide with changes in filtration efficiency, implying potential interactions between ambient conditions and filtration behavior. These relationships may be associated with combined effects of diffusion, interception, and inertial impaction processes, although further quantitative analysis would be required to confirm the dominant mechanisms. These findings provide a solid experimental basis for a deeper understanding of the performance characteristics of filtration systems under actual environmental conditions.

Correlation analysis was performed between filtration efficiency for different particle size ranges and environmental parameters, including filter differential pressure, temperature, and relative humidity. The corresponding correlation coefficients are presented in Fig. 5.

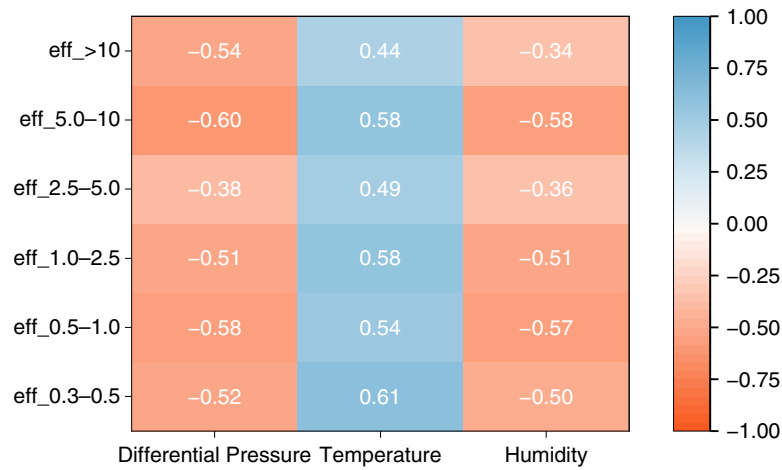


Figure 5: Correlation between filtration efficiency and various parameters of the tested filters.

The results show that filtration efficiency exhibits a moderate negative correlation with filter differential pressure, indicating that higher pressure loss is generally associated with slightly lower filtration efficiency within the investigated operating range. A positive correlation is observed between filtration efficiency and ambient temperature, whereas a weak negative correlation is identified with relative humidity. To further provide a quantitative interpretation of these relationships, empirical multivariable linear fitting was additionally performed using the filtration efficiency for particles within the 2.5–5.0 μm size range as a representative example. The fitted relationship can be expressed as:

$$\eta = 0.95T + 0.01H - 0.46P + 124.01 \quad (3)$$

where η is the filtration efficiency (%), T is the ambient temperature ($^{\circ}\text{C}$), H is the relative humidity (%), and P is the filter differential pressure (Pa). It should be noted that this empirical relationship represents a statistical fitting result rather than a direct physical causal model. The observed trends suggest that variations in environmental conditions and operating states may jointly influence filtration performance, although further controlled experiments are required to clarify the underlying mechanisms.

From a physical perspective, the observed environmental dependence of filtration efficiency can be associated with several coupled mechanisms. Variations in ambient temperature influence air viscosity and particle diffusivity, which modify particle–fiber interaction probability, particularly for fine particles dominated by diffusion mechanisms. Relative humidity affects particle hygroscopic growth and surface adhesion behavior, potentially altering particle capture stability on fiber surfaces. In addition, changes in environmental conditions may influence electrostatic interactions within fibrous media, leading to variations in particle attachment efficiency. These mechanisms may contribute to the observed stronger dependence of filtration performance on temperature compared with humidity within the investigated operating range.

4 Filter Integrity Testing

During long-term field operation, filter performance may change due to material wear, particle accumulation, and environmental exposure. Therefore, verification of filter integrity is necessary to ensure that the observed variations in pressure loss and filtration efficiency were not caused by structural damage or abnormal degradation of the filter element. After completion of the field experiments, the tested air filters were removed and transported to the laboratory for post-test inspection, as illustrated in Fig. 6.



Figure 6: Photograph of the tested air filter post-experiment.

A comprehensive post-test inspection was conducted to evaluate the structural condition of the tested filters. Macroscopic examination of the filter media was first performed using an endoscope to identify any visible damage, deformation, or structural defects. Subsequently, microscopic observations were carried out with a metallurgical microscope to investigate surface conditions and particle deposition characteristics. The endoscopic inspection revealed no observable damage, cracking, or deformation in either the cylindrical or conical filter elements, confirming that the filters maintained structural integrity throughout the long-term field operation. To further investigate particle deposition behavior, each filter was divided into upper, middle, and lower sections according to the incoming airflow direction. Representative metallographic images of the upper section of the cylindrical filter are presented in Fig. 7. Pronounced dust accumulation is observed on the upstream surface, while the downstream side remains comparatively clean, indicating that particle capture primarily occurs on the external filtration surface. Similar deposition characteristics were observed in the other sections of the cylindrical filter.

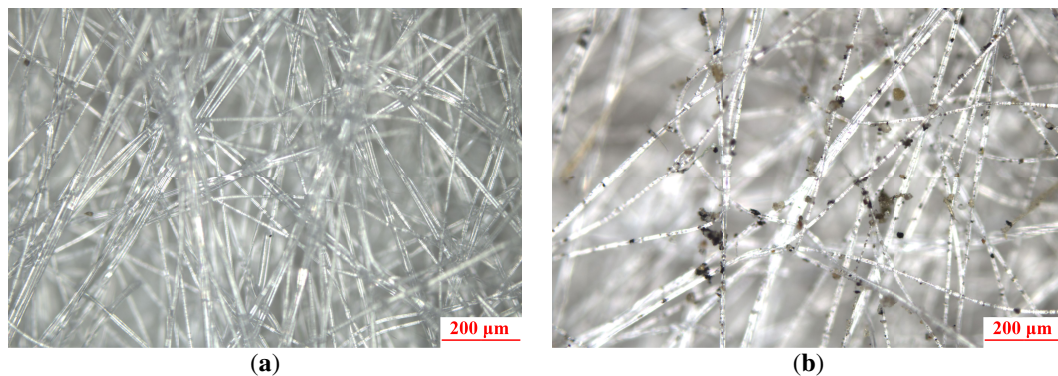


Figure 7: Metallographic photograph of the upper section of the cylindrical air filter. (a) the inner side; (b) the outer side.

A comparative analysis of deposition distributions on both filter geometries is presented in Fig. 8. The cylindrical filter shows noticeably higher dust accumulation in the upper section compared with the middle and lower sections, suggesting non-uniform particle loading along the airflow direction. This phenomenon indicates that the frontal region of the cylindrical cartridge experiences stronger particle impaction and preferential dust deposition. In contrast, the conical filter exhibits relatively uniform dust distribution across

all examined sections. The conical geometry likely promotes more uniform airflow distribution and mitigates localized particle accumulation.

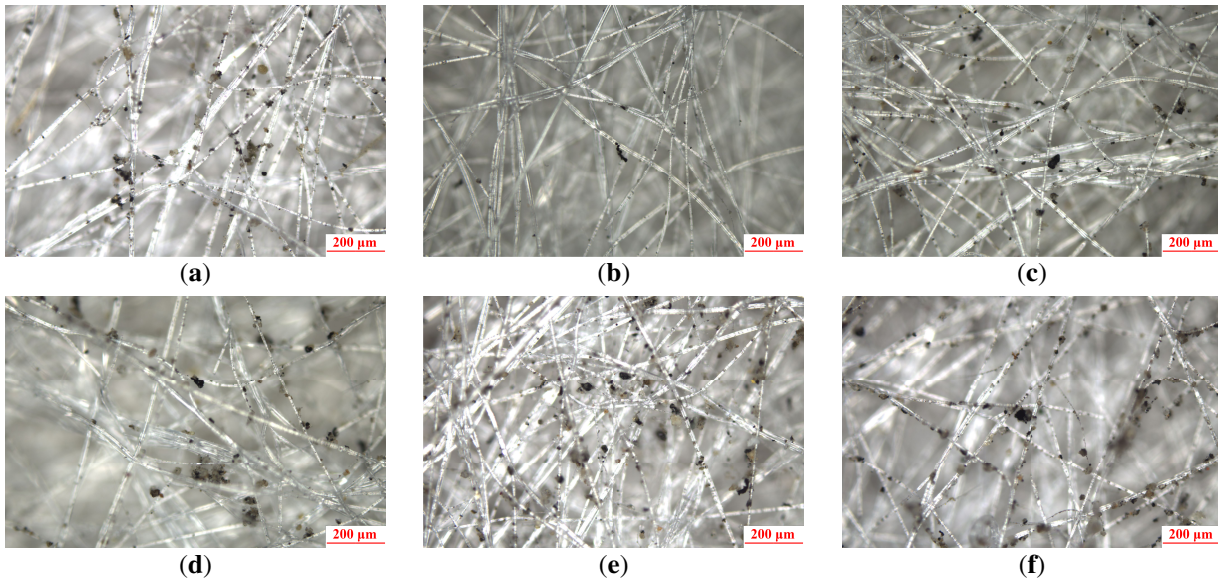


Figure 8: Metallographic photograph of the outer side of the tested filter. (a) the upper section of the cylindrical filter (same image as Fig. 7b, included here for comparison under a different analytical context); (b) the middle section of the cylindrical filter; (c) the lower section of the cylindrical filter; (d) the upper section of the conical filter; (e) the middle section of the conical filter; (f) the lower section of the conical filter.

The absence of structural damage, together with the observed deposition characteristics, confirms that the tested filters remained fully functional during the experimental period. Therefore, the variations in differential pressure and filtration efficiency reported above can be attributed primarily to operational loading and changing environmental conditions rather than filter failure or material degradation.

5 Mapping Characteristics of On-Site vs. Laboratory Testing

To evaluate the consistency between laboratory testing and practical operating performance of gas turbine inlet air filtration systems, combined laboratory and long-term field investigations were conducted. Field measurements were carried out at three gas turbine power plants operating under distinctly different environmental conditions. The selected sites represent typical scenarios encountered in practical gas turbine applications, including high-humidity environments, heavy particulate pollution regions, and industrial atmospheric conditions containing chemically active pollutants.

Site A (Yangzhou Plant) is located in an industrial region characterized by high fine-particle concentrations and the presence of potentially corrosive gaseous pollutants.

Site B (Hangzhou Plant) operates under long-term high-humidity conditions accompanied by elevated ambient temperatures during summer seasons.

Site C (Beijing Plant) is exposed to persistently high particulate matter concentrations and seasonal low temperatures, representing severe dust-loading environments.

These sites collectively cover a broad range of environmental influences affecting gas turbine inlet filtration systems, ensuring representative evaluation of field performance variability.

5.1 Laboratory Baseline Performance

Baseline filtration performance was determined under controlled laboratory conditions to provide a reference for comparison with field measurements. Laboratory tests were conducted at an ambient temperature of 14°C–16°C and relative humidity of 14%–16%, with a constant airflow rate of 2500 m³/h. DEHS aerosol was employed as the test medium, and artificial test dust specified in ASHRAE 52.1-2017 was used for dust-loading experiments. Cumulative dust loading, ranging from 0 to 1233 g, was adopted as the primary indicator of filter operating status.

Fig. 9 illustrates the evolution of filtration efficiency and pressure loss as functions of cumulative dust loading. As dust loading increases, filter resistance rises continuously from an initial value of 135 to 450 Pa, indicating progressive pore blockage and particle accumulation. Meanwhile, filtration efficiency increases from 78.5% to 99.8%, exhibiting a characteristic staged evolution: rapid improvement during the initial loading period followed by gradual stabilization at higher dust loads. The resistance growth and efficiency enhancement demonstrate a clear but nonlinear relationship. Notably, a distinct increase in filtration efficiency occurs when cumulative dust loading reaches approximately 545 g, suggesting the formation of an effective dust cake layer that enhances particle capture performance.

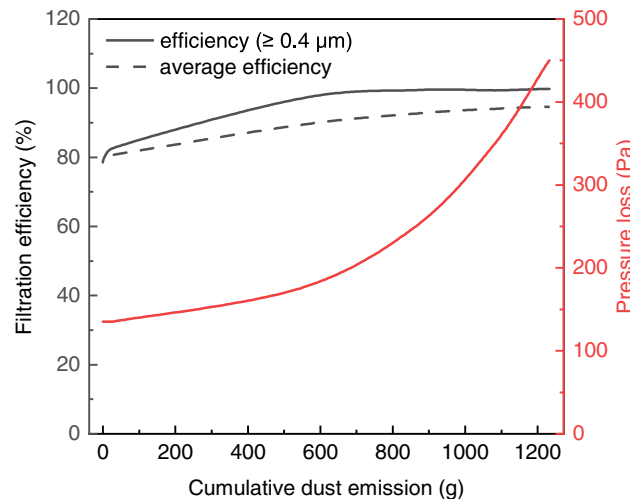


Figure 9: Variations of filtration efficiency and pressure loss with cumulative dust loading.

5.2 Field–Laboratory Comparison

To establish a direct comparison between laboratory and field performance, filtration efficiencies were measured at a fixed pressure loss of 135 Pa for particles within the size ranges of 0.3–0.5, 0.5–1.0, 1.0–2.5, 2.5–5.0, 5.0–10 μm, and above 10 μm. The comparison between laboratory benchmark results and field measurements is presented in Fig. 10.

Both laboratory and field results exhibit a consistent fundamental trend: filtration efficiency increases with particle size. This behavior agrees with classical filtration theory, in which diffusion dominates fine-particle capture while interception and inertial impaction become increasingly effective for larger particles.

Despite the consistent trend, noticeable quantitative differences exist between laboratory and field measurements. The magnitude of deviation varies among sites and becomes more pronounced under heavily polluted or chemically aggressive environments. This discrepancy may arise from environmental influences such as particle morphology variation, moisture-induced agglomeration, and chemically active atmospheric components, which are not fully reproduced under standardized laboratory testing conditions.

These factors alter particle–fiber interactions and deposition behavior, leading to deviations between controlled experiments and real operating environments. Therefore, laboratory performance alone cannot fully represent filtration behavior under practical conditions, highlighting the necessity of establishing a correction relationship between standardized testing and field performance.

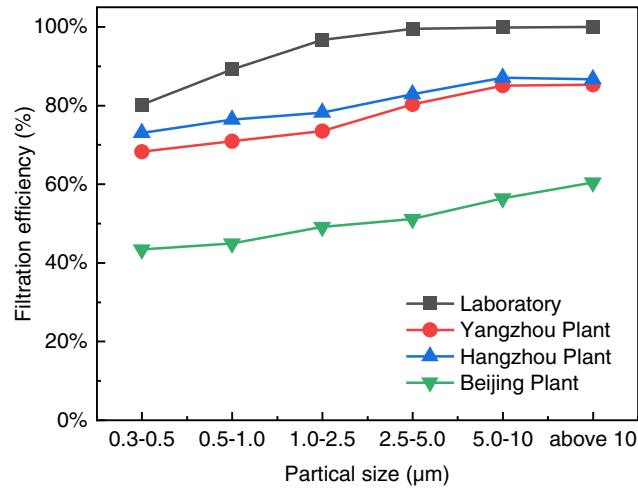


Figure 10: Comparison of filtration efficiency across different particle size ranges at a pressure loss of 135 Pa.

5.3 Establishment of Field–Laboratory Correction Factors

Based on the comparative analysis, a correction factor was introduced to quantify the mapping relationship between laboratory-tested efficiency and field-measured efficiency. The correction factor is defined as the ratio of measured filtration efficiency to laboratory-tested efficiency under standard operating conditions. The correction factors were then determined at the preset filter pressure drop condition. The detailed results are presented in Table 1, where the standard deviation represents the sample standard deviation of the correction factors across different particle size ranges for each power plant. It is evident from the table that, after selecting a specific location, the correction factors for filtration efficiency across different particle size ranges exhibit high consistency. All standard deviations are strictly controlled below 0.04, fully reflecting the stability and reliability of the data.

Table 1: Correction factors relating field-measured filtration efficiency to laboratory-tested efficiency across different particle size ranges.

Power Plant	Particle Size μm						Average Value	Standard Deviation
	0.3–0.5	0.5–1.0	1.0–2.5	2.5–5.0	5.0–10	Above 10		
Site A	0.850	0.795	0.760	0.807	0.852	0.853	0.82	0.035
Site B	0.910	0.857	0.809	0.833	0.873	0.867	0.86	0.035
Site C	0.541	0.504	0.508	0.514	0.565	0.604	0.54	0.039

Regarding the performance of individual sites: the measured efficiency at Site B is closest to the laboratory-measured efficiency, followed by Site A. However, the measured efficiency at Site C deviates significantly from the laboratory-measured efficiency, indicating a substantial practical application difference. The average correction factor enables conversion of laboratory-measured efficiency to field-measured efficiency. Experimental results show that the average correction factors, defined as the ratios of measured efficiency to

laboratory-measured efficiency, are 0.82, 0.86, and 0.54 for Site A, Site B, and Site C, respectively, indicating that the measured efficiencies correspond to 82%, 86%, and 54% of the laboratory-measured efficiency.

The relatively consistent correction factors across particle size ranges suggest that environmental influences primarily act as a global performance modifier rather than fundamentally altering individual particle capture mechanisms. This finding supports the applicability of a unified correction-coefficient approach for translating standardized laboratory results into realistic field performance predictions.

6 Conclusion

In this study, the filtration performance characteristics of gas turbine inlet air filtration systems under realistic operating conditions were investigated through a combination of laboratory testing and long-term field measurements. A laboratory testing platform and a self-developed on-site testing apparatus were employed to analyze pressure loss evolution, particle-size-dependent filtration efficiency, and the influence of environmental parameters, including temperature, humidity, and ambient particulate concentration. In addition, comparative investigations were conducted at three representative gas turbine power plants operating under different environmental conditions to establish a quantitative relationship between laboratory-tested and field-measured filtration performance. The conclusions are as follows:

- (1) Under both laboratory and field operating conditions, filter pressure loss increased progressively with operational loading. During laboratory dust-loading tests, the filter pressure loss increased from 135 to 450 Pa, while filtration efficiency increased from 78.5% to 99.8% with cumulative particle deposition. Filtration efficiency generally increased with particle size, exhibiting a slight fluctuation at the largest particle size range, and showed limited dependence on pressure loss within the investigated operating range. Short-term fluctuations in filtration performance were associated with variations in ambient particulate concentration and atmospheric humidity.
- (2) Environmental parameters exhibited statistically observable influence on filtration performance under practical operating conditions. Among the investigated factors, ambient temperature showed the strongest correlation with filtration efficiency, whereas humidity and pressure differential exhibited comparatively weaker correlations. The observed environmental dependence may be associated with coupled effects including particle diffusivity, hygroscopic growth, particle–fiber adhesion behavior, and electrostatic interaction within fibrous filter media.
- (3) Laboratory and field measurements demonstrated consistent trends of increasing filtration efficiency with particle size; however, significant quantitative deviations were observed under actual operating environments. The average correction factors relating field-measured efficiency to laboratory-tested efficiency were determined as 0.82, 0.86, and 0.54 for the three representative power plants, respectively, indicating that standardized laboratory evaluation may substantially overestimate practical filtration performance under certain environmental conditions. Based on these observations, a correction-coefficient approach was developed based on the investigated sites to provide a quantitative mapping relationship between laboratory certification results and field operating performance, offering practical guidance for filter selection, performance evaluation, and operational management of gas turbine inlet air filtration systems.

It should also be noted that the present study was conducted under limited representative environmental conditions, and the proposed field–laboratory mapping relationships were established based on field monitoring data from specific operating sites. Therefore, the applicability of the correction-coefficient approach may still depend on local atmospheric characteristics and operating conditions. Future work should further expand long-term field investigations under broader climatic environments and incorporate

additional factors such as particle composition, morphology, and transient operating conditions to improve the universality and predictive capability of field–laboratory performance mapping methods.

Acknowledgement: Not applicable.

Funding Statement: The authors received no specific funding for this study.

Author Contributions: Conceptualization, Yan Shi and Rong Zhuang; methodology, Yan Shi and Rong Zhuang; software, Yunshan Bai; validation, Yunshan Bai; formal analysis, Wenguo Xiang; data curation, Wenguo Xiang; writing—original draft preparation, Yan Shi; writing—review and editing, Wenguo Xiang and Cai Liang; supervision, Rong Zhuang; All authors reviewed and approved the final version of the manuscript.

Availability of Data and Materials: The data that support the findings of this study are available from the Corresponding Author, Yan Shi, upon reasonable request.

Ethics Approval: Not applicable.

Conflicts of Interest: The authors declare no conflicts of interest.

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