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Review of Standards, Localization and Performance Improvement of Pulse Air Inlet Filters for Gas Turbines

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1. ABSTRACT

This extended abstract presents a comprehensive study on the reverse engineering, localization and technical validation of a dual-stage Pulse Air inlet filter (comprising a conical CO-2612 and a cylindrical CY-2612 element) originally manufactured by Camfil. Due to the unavailability of precise manufacturing data, a reverse engineering process was conducted by disassembling the original filter. The original filter media, classified as F9 according to EN-779:2012, was determined to be a moisture-resistant composite of cellulose and synthetic fibers. Subsequently, a domestic replacement filter was manufactured using an AHLSTROM media (90/40 E PE K WB2-G), which also meets the F9 filtration class. To enhance performance, a nanofiber layer was added to the localized media. Performance testing of the localized filter assembly, conducted according to EN-779:2012 standards, showed an overall efficiency of 96.30% and an initial total pressure drop of 121 Pa across both elements (compared to 211 Pa for each original element). The integration of the nanofiber coating significantly improved dust holding capacity and initial efficiency, facilitating easier cake release during the pulse-cleaning cycle. The results confirm that the indigenously manufactured filter meets or exceeds the performance specifications of the original unit, offering a reliable and cost-effective alternative for gas turbine air intake systems.

Keywords: Filtration, Gas Turbine, Pulse Cleaning, Nanofiber Coating, Localization, EN-779:2012.

2. INTRODUCTION

The continuous and reliable operation of gas turbines, especially in challenging environments like the Middle East where dust storms are frequent, heavily relies on the performance of their inlet air filtration systems. Surface loading filters, utilizing pulse-jet cleaning mechanisms, were developed in the 1970s specifically to manage high dust concentrations without frequent media replacement [1]. In this method, air passes through high-efficiency cartridge filter elements, trapping contaminants on the media surface. The cleaning cycle is automatically initiated when the pressure differential (ΔP) reaches a set threshold, where a short, high-pressure pulse of air cleans the media surface [2]. A key feature of surface filtration is that efficiency increases as the dust cake builds up, acting as an additional filtration layer [2].

Numerous studies have focused on optimizing filter media and the cleaning process. For example, Akdoğan et al. demonstrated that adding an electrospun nanofiber layer to the media causes contaminants to deposit on the surface rather than penetrating deeply, allowing for easy removal via an air pulse [3]. This technique generally leads to longer filter life, lower pressure drops, and improved efficiency [3].

While a significant body of knowledge exists regarding the operation and selection of filters tailored for specific turbine operating regions, the primary challenge in our country, given the sanctions, is the localization of these filters to reduce dependency on foreign sources. Despite extensive foundational knowledge, documented research focusing specifically on the reverse engineering and localization of these high-performance pulse-jet filters remains scarce.

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Therefore, this research first reviews the relevant standards and fundamental design principles for gas turbine inlet air filters. Subsequently, it documents the successful practical model of localizing the inlet air filter for the gas turbine at the Bushehr Petrochemical Complex, which was originally supplied by the Swedish company Camfil.

3. MATERIALS AND METHODS

All materials and methods used in this work are detailed below, structured around the reverse engineering process and the development of the localized filter.

3.1. Original Filter Specifications

The original Camfil filter system consisted of two main elements: a conical element (CO-2612) and a cylindrical element (CY-2612). Key features include an F9 filtration class for both elements, The total filtration area was 46.81 m² with an initial total pressure drop of 422 Pa (calculated from 211 Pa for each component).

3.2. Disassembly and Reverse Engineering

Due to the manufacturer's refusal to provide detailed structural information, the filter was cut open to extract necessary data and verify existing technical documentation. The assembly map of the filter is shown in (Figure 1).

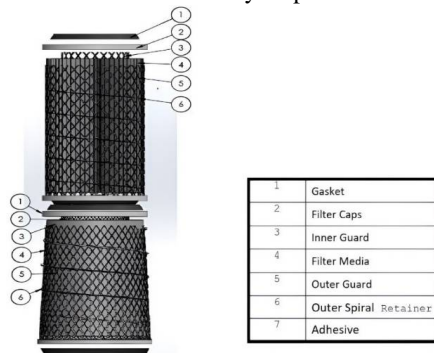


Figure 1. Filter assembly drawing

Post-disassembly analysis confirmed that the filter media was a moisture-resistant composite of cellulose and synthetic fibers. The internal and external guards were constructed from 0.5 mm expanded galvanized carbon steel to support the media and enhance resistance to applied pressures. The top and bottom caps were made of galvanized carbon steel, fitted with permanently adhered nitrile rubber seals to ensure optimal sealing during installation. The media was attached to the outer guard using a spiral pattern of hot-melt adhesive. The final assembly of various components was secured using polyurethane adhesive.

3.3. Localized Filter Specifications

Following data extraction, a suitable replacement filter was specified based on domestic manufacturing capabilities and standards, leading to the creation of the localized filter components. All parts of the localized filter were manufactured to match the original dimensions and materials.

3.3.1. Replacement Media Characteristics

The replacement media used in the localized sample, similar to the original, is a cellulose/synthetic fiber composite with an F9 filtration class (EN-779:2012). This media is composed of resin-impregnated, water-resistant cellulose and synthetic fibers. The specific AHLSTROM media used (90/40 E PE K WB2-G) consists of 80% cellulose and 20% synthetic fibers. Crucially, to improve the performance of the introduced media, a nanofiber layer was added to the base substrate in the localized filter.

3.3.2. Application of Nanofiber Coating to the Media

The application of a nanofiber coating is an advanced technique to increase dust holding capacity, improve initial efficiency, reduce operational pressure drop, and ultimately extend filter life. In sensitive applications like gas turbines, this technology offers superior protection compared to traditional media [4]. The nanofiber layer creates a much finer surface structure with smaller pores compared to standard cellulosic media. A comparative analysis shows that all performance characteristics of standard media are improved after the addition of nanofibers. Scanning Electron Microscopy images (Figure 2) clearly illustrate the surface difference before and after the nano-coating application [5].

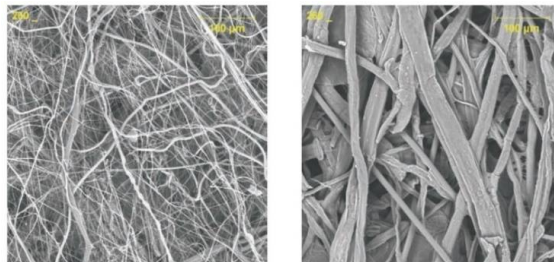


Figure 2. Right, image of the substrate before adding the nano coating and left, after (magnification 260x)



4. RESULTS AND DISCUSSION

The performance of the localized filter was compared against the reference filter using the data sheet in the technical specifications and the functional test results. Table 1 provides a direct comparison of the key features.

Table 1. Example table for the extended abstract

Parameter	Original Filter	Localized Filter	Relative Difference (Localized vs. Original)
Filtration Class	F9	F9	No change
Total Initial Pressure Drop (Pa)	422	121	↓ 71.33 %
Total Filtration Area (m ²)	46.81	43.10	↓ 7.93 %
Efficiency at 1 μm Particle Size (%)	99.95	96.30	↓ 3.65 %
Air Flow Rate (m ³ /h)	2323	2500	↑ 7.62 %
Moisture Resistance (%)	100	100	No change
Operating Temperature (°C)	80	80	No change
Final Estimated Cost per Set (million IRR)	12	8	↓ 33.33 %

4.1. Comparative Performance Analysis

The primary objective of this research—the reverse engineering and localization of high-performance gas turbine inlet filters previously dependent on proprietary Swedish Camfil technology—was successfully achieved. Table 1 clearly demonstrates that despite a reduction in total filtration area (from 46.81 m² in the original to 43.10 m² in the localized version), the domestically manufactured filter successfully matched the performance standard, achieving an equivalent F9 filtration class. Most significantly, the initial total pressure drop was drastically reduced from 422 Pa (Reference) to 121 Pa (Localized), representing a remarkable 71.3% reduction in initial flow resistance. This significant outcome is strong evidence for the success of the engineered nanofiber coating, which shifted the filtration mechanism toward surface loading, thereby preventing deep media clogging. This design shift yields substantial benefits, including reduced procurement costs due to lower material consumption, improved initial turbine efficiency from lower starting pressure drop, and extended operational life. Although the original filter maintained a slight advantage in 1-micron particle efficiency (99.95% vs. 96.30%), the localized filter confirmed a highly successful localization effort by achieving the F9 class at a higher airflow rate (2500 m³/h vs. 2323 m³/h) and significantly lower initial resistance, promising major overall operational cost reductions across the system.

5. CONCLUSION

The main finding of this research is the successful reverse engineering and localization of the Camfil Pulse air intake filter. The localized filter, utilizing the AHLSTROM 90/40 E PE K WB2-G media enhanced with a nanofiber layer, achieved the required F9 filtration class while significantly improving operational characteristics. The most critical achievement is the 71.3% reduction in initial total pressure drop (121 Pa vs. 422 Pa) coupled with an increase in total airflow capacity (2500 m³/h vs. 2323 m³/h). These combined improvements lead directly to lower initial energy consumption and the extended filter life, realizing substantial operational cost savings for the gas turbine system. While the reference filter showed a marginal advantage in capturing 1-micron particles, the significant performance gains in flow resistance and capacity strongly validate the localization approach.

Future work should focus on long-term field testing of the nanofiber-coated media under various environmental conditions and investigating alternative domestic media compositions to match or exceed the 1-micron efficiency benchmark of the original filter.

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