

USER GROUP ACTIVITIES

Proper filter selection a prerequisite for reliable GT operation

By Terry Brown, Gas Turbine Systems Inc, and Lisa Beeson, Quietly Making Noise LLC

A defining characteristic of the Combustion Turbine & Combined Cycle (CTC²) Users' Organization is the practical problem-solving it does on behalf of member companies; research that later is offered for sale to non members. The goal always is to reduce O&M cost and improve reliability. Recently, the group sponsored an in-depth study of inlet air filters for gas turbines (GTs) that examined user experience, reviewed the offerings of manufacturers, and identified the criteria important to proper selection and application.

Goal of the work conducted by Gas Turbine Systems Inc and Quietly Making Noise LLC was to help powerplant owner/operators make better decisions regarding filter selection, operation, maintenance, inspection, etc—all to prevent, to the extent possible, a situation that could lead to compressor damage.

The widespread application of GTs in recent years has placed these versatile machines in virtually every type of ambient environment that exists on Earth. Site environment is important because it impacts significantly GT performance as well as selection and maintenance of the inlet air filters so important to efficient operation. When these consumables are neglected, adverse operational and cost impacts often result.

On the surface, many air filters for GT application appear the same. Functionally, most operate in the same manner. But don't be fooled: There are substantial differences among competing offerings. Selecting an inappropriate filter means more frequent replacements, at a minimum. An ineffective filter can adversely affect GT performance, resulting in more frequent wash cycles and more rapid internal wear. The last threatens to reduce overhaul intervals and availability.

Filtration basics

First step in purchasing replacement filters is the development of a meaningful specification. This requires knowledge of standards to ensure that the filters bid by various manufacturers will perform as intended for your particular application and that the bids will be comparable.

Important to note is that no single standard exists regarding inlet air filters for GTs. However, the power industry generally relies on several well-established standards developed by the Atlanta-based American Society of Heating, Refrigerating, and Air-Conditioning Engineers. These include ASHRAE 52.1-1992 and 52.2 test methods related to minimum efficiency reporting values (MERV). Their intent is to establish defined procedures for classifying filter performance using pre-established methods, equipment, and processes. Here are the ones you should be familiar with:

- **Test air flow rate** is the flow rate at which the filter is tested. It should reflect the rating of the filter for the GT intake application.
- **Initial resistance** is the differential pressure measured across the filter when it is *new* and *clean*.
- **Final resistance** is the differential pressure measured across the filter when the manufacturer recommends replacement.
- **Initial atmospheric dust-spot efficiency** is a measure of the effectiveness of the filter to remove particulate matter using a comparison of optical densities (staining), *prior* to introduction of the test dust.
- **Average atmospheric dust-spot efficiency** is a measure of the effectiveness of the filter to remove particulate matter using a comparison of optical densities (staining). This test considers the amount of test dust introduced at incremental stages, which is then averaged.
- **Average dust weight arrestance** is the weight of the captured dust, measured incrementally to the point when the final



Brown



Beeson

resistance is attained. The measured weight then is averaged. However, this can be a misleading term. Although the large particles comprise most of the weight, it is the smaller particles that are most apt to pass through the filter media and be ingested into the compressor. This is the reason that filter efficiency by physical size (microns) is important.

■ **Dust holding capacity** is a relative measure of filter service life and the amount of dust (by weight) that the filter retained at the final measured resistance.

Additionally, the ASHRAE test specification requires a physical description of the filter: specifically, face dimensions, depth, media area, and type of media.

Filter classification falls into two primary categories based on the test methods defined by ASHRAE. These are arrestance and efficiency. However, efficiency also should be measured for specific particle-size ranges. It is through this more precise measurement that the effectiveness of a filter can be determined. Recent guidelines for particle ranges suggest that filtration efficiency should be measured for particles from 0.3 to 1 micron, from 1 to 3 microns, and from 3 to 10 microns.

Finally, remember that atmospheric air filters historically have been grouped based on ASHRAE average atmospheric dust-spot efficiency results. Accordingly, they can be grouped into three application categories: commercial, high-efficiency particulate (HEPA), and super-ultra-low penetration (SULPA) air filters. GT applications focus on commercial and high-efficiency filters.

Specifications

Commercial air filters have nominal efficiency ratings ranging from 10% to 90%. For GT application, filters are further defined as:

- Prefilters, 20%-40% efficient.
- Intermediate, 40%-60% efficient.
- Final, 60%-90% efficient.

High-efficiency particulate air filters (HEPA) and DOP-rated filters are finding increased application in environments requiring higher levels of particulate-removal efficiency. The Institute of Environ-

BOOK REVIEW

HRSG Users Handbook a valuable resource

520 pages, 6 x 9 in., hard cover, \$345, order online at www.HRSGusers.org

The knowledge base for proper design, operation, and maintenance of that special class of power boilers known as heat-recovery steam generators (HRSGs) essentially resides in the minds of a thousand or so engineers. Surprising as it may seem, relatively little generic information on the subject has been compiled in print and in the electronic domain.

Every HRSG manufacturer certainly provides each customer "instructions for operation and maintenance" of the particular unit purchased and conducts sufficient classroom training to safely start up, run, and shut down the boiler. That information is valuable, of course, but it doesn't get you very far. Think of college education as an analogy: It provides the basics and a sense of what your chosen field is all about, but you really do not gain knowledge and perspective until you work diligently at something for a long time—hopefully under the direction of an experienced mentor.

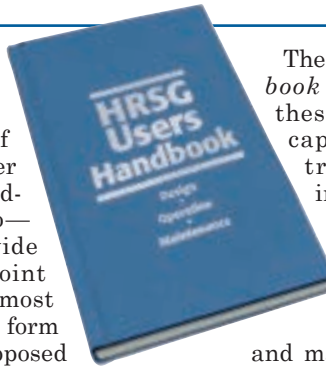
HRSGs are almost a forgotten child of an electric power industry transitioning from a regulated market to a competitive one, where *real* knowledge is the key to profitability. An interesting result of this paradigm shift has been the birth and development of user groups in the gas-turbine (GT) sector of the industry, each focusing on a specific engine model. These ad hoc groups were born of necessity—confederations of like-minded people striving to develop a viable methodology for producing reliable, efficient, and virtually pollution-free electrical energy.

The HRSG User's Group was founded in 1993 to help participants solve problems associated with the steam-cycle portion of GT-based combined-cycle and cogeneration plants. It is unique among user groups serving this sector of the market in that all conference and workshop sessions are open to users, consultants, and manufacturers alike—not just users. The benefit of this format is that it provides the broadest possible per-

spective and experience base.

The HRSG User's Group also is unique in terms of "deliverables." The GT user groups publish no "proceedings"—written or audio—although some may provide copies of vendor PowerPoint presentations. And since most of the interchange is in the form of verbal discussion, as opposed to prepared presentations, you return to your plant only with what's in your head and notebook.

By contrast, the in-depth content of HRSG User's Group conferences is captured by a veteran plant manager/experienced industry editor and provided to each attendee as part of his or her registration fee. Typical reports are 50 pages or more.



The *HRSG Users Handbook* goes well beyond these meeting reports, capturing the industry's best thinking in far greater depth and clarity, thereby establishing itself as an invaluable guide to the design, operation, and maintenance of heat-

recovery boilers. The information presented has never been compiled previously in such detail and made available at an affordable price. To provide some perspective on the unique nature of this work, consider that the recently issued 41st edition of the revered *Steam*, published by The Babcock & Wilcox Co, contains nine pounds worth of boiler engineering know-how between its covers but devotes only two pages to HRSGs.

There is no doubt in my mind that the *HRSG Users Handbook* will achieve "bible" status within the combined-cycle/cogen community. Its content is based on sound engineering principles and lessons learned—often painfully. The various chapter authors are experts in their respective fields who have participated in HRSG User's Group meetings and know first-hand the information needed to achieve operational excellence and a sound balance sheet in the merchant power business.

The contributors were hand-picked by Rob Swanekamp, arguably the most technically grounded editor in the power industry today. Swanekamp, like his handbook, is unique. He is a visionary and tireless worker, a registered professional engineer with nearly two decades of hands-on powerplant management experience who trained himself to become an excellent communicator in both the spoken and written word. Proof of the latter is his rapid ascension to chief editor of *Power* magazine in a brief career at McGraw-Hill. Today, Swanekamp is the executive director of the HRSG User's Group; he has been directly involved in the organization's activities for nearly all of its 14 years.

HRSG Users Handbook should be required reading for all who manage or operate a GT-based combined-cycle or cogeneration plant. It is a foundation upon which all HRSG users can build more reliable and efficient generating facilities.

BOB SCHWIEGER
Editor and Publisher
COMBINED CYCLE Journal

Content easy to digest

Here's a chapter-by-chapter preview of the information you'll find in the *HRSG Users Handbook*, which was written to be understood:

- 1. Operational safety.**
- 2. HRSG design**, with subchapters on writing specifications and on vertical and small boilers.
- 3. Commissioning and initial startup**, including steam-system cleaning and initial performance testing.
- 4. Steam system operation** has subchapters on best practices, steam bypass systems, duct burner operation, attemperators.
- 5. Performance monitoring** of the HRSG and of the steam turbine and condenser.
- 6. Water treatment**, has subsections on HRSG failure mechanisms, makeup water treatment, steam-cycle chemistry, HRSG layup, cooling-water treatment, and water-chemistry automation.
- 7. Emissions control and CEMS.**
- 8. Maintenance program development.**
- 9. HRSG maintenance** including standard practices, how to find and fix tube leaks, welding tube-to-header joints, NDE tools, special maintenance practices.
- 10. Piping systems, including the basics** and special piping.
- 11. Valve maintenance.**
- 12. Ductwork, dampers, and stacks.**
- 13. Duct-burner maintenance.**
- 14. Instrumentation and controls.**
- 15. Plant staffing, organization.**
- 16. Failure analysis.**
- 17. Outage management.**

Alternative inlet filters for GT service



Prefilter, pad type



Prefilter, pleated type



Final filter, mini-pleat type



Final filter, panel type



Self-cleaning filter, crossflow type



Self-cleaning filter, upflow type

mental Sciences, Rolling Meadows, Ill, defines these filters as having “. . . minimum particle-collection efficiency of 99.97% for 0.3 micrometer [micron] thermally generated dioctylphthalate (DOP) particles or specified alternative aerosol, and a maximum clean-filter pressure drop of 1 in. w.g. when tested at rated air flow capacity.”

Table compares filter arrestance and efficiency (based on ASHRAE 52.1-1992 and 52.2 test methods), MERV, and European standards (EN 779/1882).

Filter impacts on GT operation. Here are some general “rules” to keep in mind regarding air filters and how they impact GT-based powerplant operations:

1. Air filters are tested and rated based on their ability to remove dry airborne dust.
2. As filter efficiency increases, resistance increases, given the same air volume.
3. Filter life decreases as resistance increases.
4. As filter life decreases, operational costs increase.

There are several additional factors critical to the performance of air filters. These all relate to filter effectiveness and can be qualified as follows:

- Environments that range from moisture-free to ultra-high-humidity.
- Icing, including hoar frost and ice fog.

- Chemicals, including hydrocarbons.
- Corrosive materials, including marine salt.
- Seasonal activity, ranging from insect swarms to pollens to farming practices.

Ambient air filters are critical for protecting GTs against the ingestion of contaminants that would foul or erode compressor blades, cooling-air passages, fuel atomizing jets, hot-gas-path parts, etc.

The demand for improved air filtration has increased dramatically over the years. The first land-based GTs essentially were aircraft engines modified for use as mechanical drives. These engines were capable of ingesting moderate amounts of contaminants without service interruption. In fact, there still are a relatively large number of engines of this vintage in reliable peaking service

that don't have (and never had) air filters or even bird screens.

However, as high-performance land-based GT designs evolved and service conditions became more demanding, the need for efficient filtration became necessary to protect machines valued in the tens of millions of dollars.

Static filtration systems

Each GT manufacturer (OEM) has developed a set of intake-air filtration requirements to meet its particular needs. As noted above, no industry-wide standard exists, but what has evolved is more of a general “understanding” of the elements that comprise intake filtration systems. The two basic filter system designs—static and self-cleaning—are described here. A more complete description is contained in the CTC² report.

Static filtration systems include those that use *impingement, interception, and straining* type filters as described by the National Air Filtration Assn (NAFA), Virginia Beach, Va. All accumulate, or collect, airborne contaminants. Replacement is based on the differential pressure (resistance) across the filter, or at the end of the manufacturer's established life cycle.

Static filtration systems generally are characterized by multiple stages of filtration because that usually is the most economical arrangement. By gradually increasing the filtration efficiency from “coarse” (prefilters) to “fine” (final filters), cost-effective protection is provided (see figures).

Prefilters find application in all types of environments. Prefiltration infers that multiple stages of media filtration are used. The prefilter has the lowest efficiency and replacement cost compared to other stages. These filters typically are made of fiberglass or synthetic materials and are classified as pads, pleats (pleated filters), socks/wraps, or panels.

Final filters offer maximum protection to GT components and ultimately determine the success of the air inlet system design. These filters generally are rated at about 90% efficiency, although higher efficiency ratings are becoming increasingly cost-effective.

The initial, clean resistance of final filters—typically referred to as panel, mini-pleat, cartridge, or

Comparing ASHRAE and European standards

Efficiency, %	Arrestance, %	MERV	European class
Less than 20	60-80	1-4	G1-G2
Less than 20	80-90	5	G3
20-30	90-95	6	G4
25-30	90-95	6-7	G4
30-40	95	7-8	G4
40-50	95-98	8-9	F5
50-60	98	9-10	F5
60-70	99	10-11	F6
70-80	99	12-13	F6
80-90	99	13-14	F7
90-95	99	14-15	F8
95 DOP	NA	16	H11
99.97	NA	NA	U13-U14
99.99+%	NA	NA	U15

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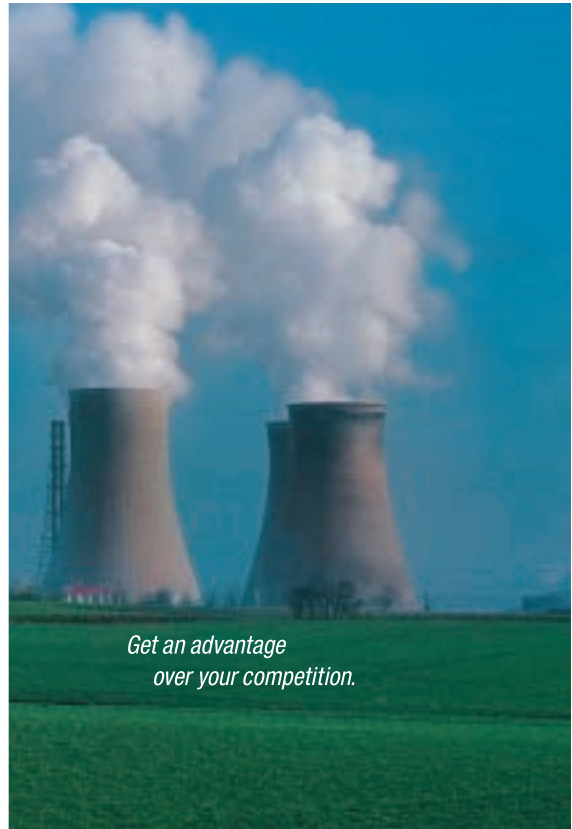
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bag—typically ranges from 0.8 to 1.0 in. H₂O. Actual resistance is determined primarily by efficiency rating and the velocity of air through the filtration medium. This typically is specified as face velocity, which has units of cfm.

Self-cleaning systems

Self-cleaning filtration systems use the same filter processes as static systems, but rely on a “reverse pulse” of compressed air for removing dust that accumulates on the media surface. The term “pulse jet” also is used. Both terms have universal acceptance and interchangeability.

Functionally, self-cleaning filters are the same as static filters in that dust is prevented from entering the clean air stream. The fundamental difference is that the self-cleaning media is formulated to ensure *surface* loading rather than the *depth* loading of static filters.

The process of self-cleaning relies on a momentary release of compressed air, directed against the interior of the filter (from the dirty-air side). It creates a shock wave that flexes the media and loosens accumulated dust. As the pulse of compressed air is released, the flow of ambient air is stopped momentarily thereby allowing dislodged dust to fall away from the filter. Removal

is by gravity or via a scavenger (secondary) air system.

Filter orientation can either be horizontal (same configuration as static filter systems) or vertical. These generally referred to as *crossflow* or

upflow arrangements and require different styles of filter cartridge.

Once the filter-media type and efficiency have been established, selection should be based on a combination of factors that can be demonstrated only by laboratory testing. Initial resistance is the best indicator of the amount of media contained in the filter. However, evaluation of filter performance, based on retained dust (within the media fibers) will, in combination with the media's ability to release captured dust, be critical factors in selecting the self-cleaning filter.

Self-cleaning filters typically are cylindrical/conical or flat pleated panels produced in a vee shape. Two basic types of filter media are used in GT applications; however, product variations impact efficiency, media resistance, and moisture resistance.

The turbine manufacturer's recommendations with respect to inlet air filters are your first line of defense against contaminant ingestion. However, the one variable constantly changing is site environmental conditions. These must be evaluated regularly to identify conditions outside of the *normal* allowances addressed in OEM specifications. When these issues are addressed, maximum performance can be achieved by the air filtration system. Every owner/operator *must* review historical data to determine the ambient conditions that most influence the successful

USEA board elects new directors

The United States Energy Assn (USEA) board elected four new directors at its regularly scheduled meeting in December. The new directors are John Krenicki, president/CEO, GE Energy; John Hofmeister, president, Shell Oil Co; Kraig Naasz, president/CEO, National Mining Assn; Richard Sergel, president/CEO, North American Electric Reliability Council.

Naasz and Sergel replace their predecessors on the board; Krenicki and Hofmeister fill vacancies. In a separate action, Sheila Hollis, a partner in the law firm of Duane Morris, was appointed chair, USEA Nominating Committee.

The COMBINED CYCLE Journal is a USEA member. Prospective members should contact Executive Director Barry Worthington (bworthington@usea.org, 202-312-1230).

Visit the organization's website at www.usea.org.

operation of the GT.

Selection of the proper filter to meet site operating needs is absolutely critical to achieving the objectives established for the air filtration system. All components must be evaluated individually and as a system: The filter housing, method of air filtration, and the filter itself must work in concert to meet established goals. Careful review of the systems installed in operating plants can result in significant cost reduction and cost-avoidance.

For further insight on the subject, refer to NAFAs guide to air filtration. It describes the various aspects of air filtration and presents an overview of the basic types of filters available commercially. ASHRAE can provide descriptions of test standards that assist in understanding and comparing competitive products; the filter manufacturers, guidelines for application of their products. The CTC² product ties all of this information together with original research on actual experience in one cohesive package. For more information on this report and other engineering solutions sponsored by CTC², contact Managing Director Doug Vandergriff,

CH2M Hill Power at dvandergriff@lg.com, or visit www.ctc2.org.

READER COMMENT

Of Rockwell and others

In reading "Special workshop explores P91/T91 issues, impending ASME Code changes" in the last issue of the COMBINED CYCLE Journal, p 2, hardness values provided on p 10 are identified as Rockwell B scale. These values appear extremely high. Are they properly Rockwell B scale? They appear more likely Vickers or Brinell 3K.

BARRY M SMITH, PE
Barry M Smith, PE, Inc
Orlando, Fla

Author's reply. The hardness levels cited on p 10 are actually Brinell 3K scale, not Rockwell B. Barry Smith's astute reading underscores the larger point made in the article: Hardness readings are a difficult way to determine the integrity of P91 materials, because of the vagaries of testing hardness in the field and because of the many different scales that exist. The industry needs a better method.

USER GROUP ACTIVITIES

ROBERT W ANDERSON
Competitive Power Resources
Palmetto, Fla

Powerplant water chemistry course

Dr Otakar Jonas, PE, well known in HRSRG (heat-recovery steam generators) circles for his work on flow accelerated corrosion, brings his practical short course, "Water Chemistry and Corrosion Control and Failure Prevention in Steam Systems," to the University of Calgary, March 28-30.

Participants will learn how to prevent failures and damage in steam systems through a better understanding of cycle operation and water chemistry, timely inspections, diagnostic monitoring, and preventive maintenance.

Jonas, who has been published in scores of periodicals, including the COMBINED CYCLE Journal, has over 30 years of experience in corrosion, steam generation, water chemistry, materials engineering, R&D, troubleshooting, instrumentation, and teaching.

To register, e-mail Jonas at jonas-inc@steamcycle.com or call 302-478-1375. Visit www.steamcycle.com for conference details.

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