AIR FILTER GUIDE FOR GAS TURBINES

Equipment selection recommendations for all climatic conditions

BETTER AIR IS OUR BUSINESS®

AAF INTERNATIONAL

AIR FILTER GUIDE

FOR GAS TURBINES

This booklet has been prepared as a guide for the selection of filtration equipment and other environmental control equipment for operation of a gas turbine.

Properly conditioned intake air is vital for top operating performance of a turbine. Filtration equipment is required to protect against excessive wear and some type of tempering equipment is often required to maintain the intake air at the right temperature and humidity levels for maximum horsepower output.

Acoustical treatment of the intake and exhaust and enclosure of the equipment is important for safe operation. Equipment selection is dependent upon many factors - dust concentration in the area - climatic conditions - space limitations. Each factor requires a different equipment selection and AAF International has the equipment, and know-how, to design a complete turbine package for operation anywhere in the world under any climatic conditions.

ENVIRONMENTAL CONDITIONING OF INTAKE AIR FOR GAS TURBINES IS REQUIRED FOR SEVERAL REASONS:

- Prevention of erosion and fouling of axial compressor blades.
- Reduction of corrosion of the compressor air path and blading.
- Reduction of corrosion in hot gas area.
- For weather protection.
- For cooling
- For sound attenuation.
- For prevention of inlet icing.

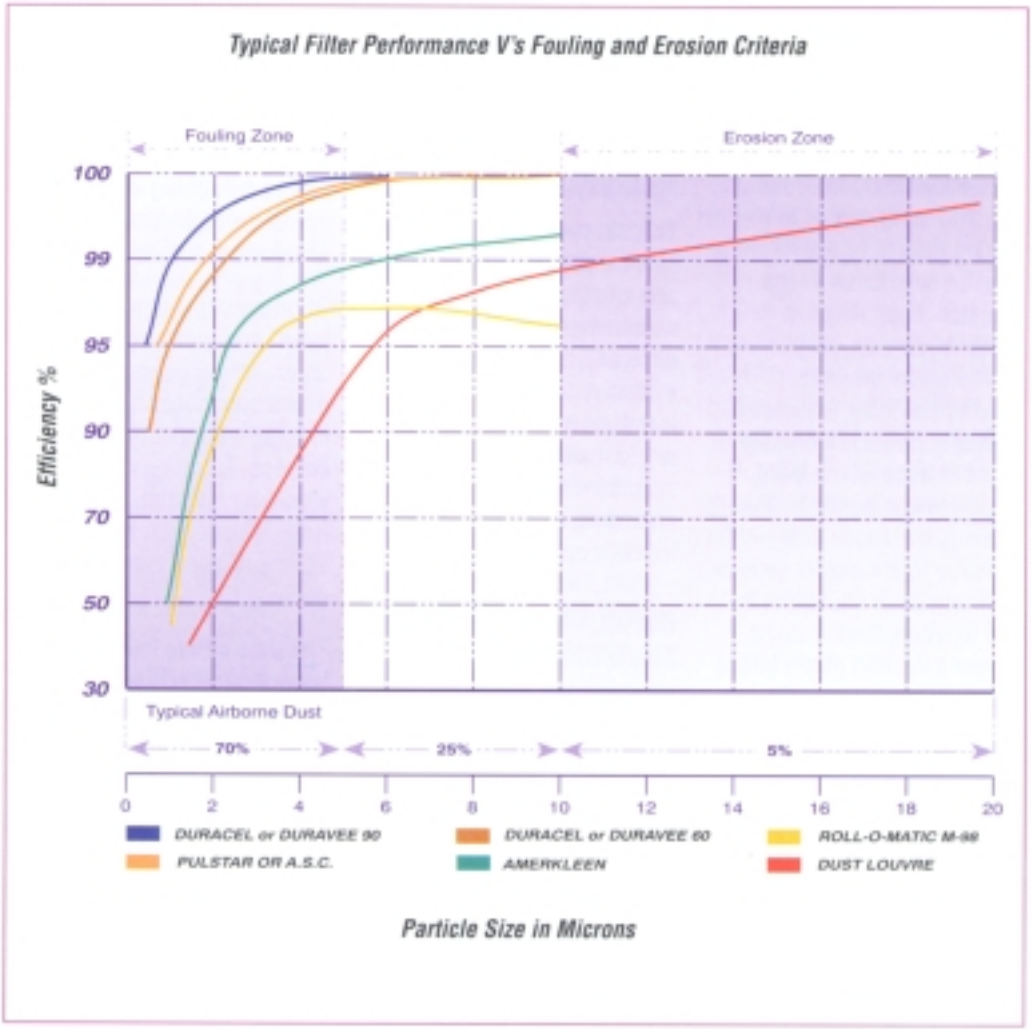


Figure 1 gives typical filter performance versus the fouling and erosion criteria.

FOULING AND EROSION

Compressor fouling is normally due to one of two elements. The first is solid particulate mineral and/or plant matter and the other is carbon smokes and/or hydrocarbon fume which create a sticky "fly paper" substance when deposited on the turbine blades.

One contributing source of carbon smokes and hydrocarbon fumes is the gas turbine itself with its exhaust combustion gases and lube-oil tank vent vapours; however, this is but a portion of the total problem considering the vast number of sources of air pollution in evidence today.

While a coarse mineral dust may erode the rotor and stator blades, a fine, sticky dust would create deposits on the blades. In both cases the profile of the blade is changed from its ideal design shape with subsequent continuous drop in the efficiency of the compressor. What differentiates both cases, is that in the former the damage is permanent, and the parts must be replaced; while in the latter the dirty parts can be cleaned. This fundamental difference in the nature of the damage caused, determines the choice of a suitable intake air filter.

Generally, average air-borne dust does not in itself result in ambient corrosion of the compressor blading. However, moisture and airborne aerosols (such as those containing sea salt or ammonium compounds) may cause appreciable corrosion of the axial compressor as well as the hot gas power turbine.

Gas turbine environments

Gas turbines are called upon to operate in virtually all types of environments from the hot, arid sandy areas of the Sahara desert, to the freezing, moist, snow-laden Arctic climates. Each location presents its own set of corrosion and fouling conditions. Table 1 shows typical conditions normally found in each of the eight basic environmental locations. In many instances it is possible to encounter several environmental situations in one location, thus making proper selection of the intake filters more critical.

When feasible, future conditions, such as new industries, should be considered when selecting environmental conditioning equipment.

The dust concentration, particle sizes, temperature and weather conditions which are shown in table 1 are typical only and are the extremes likely to be met at locations anywhere in the world. Exact data for a specific installation site should be obtained for each installation location.

RURAL COUNTRYSIDE ENVIRONMENT

The specific site conditions must be considered - is the area primarily forest - or prairie/farming land where wind blown dust especially during ploughing season may introduce high concentrations of the erosive dust.

Of prime importance in the forest and green countryside areas, would be weather protection, either hoods or louvres with trash/bird screens. Filtration required would be minimal, possibly Roll-O-Matic with M-98 media or AmerKleen Type M-80 pads.

The dust louvre inertial separator should be considered in farming and prairie areas where blowing dust during ploughing season and in autumn would subject the turbine to large quantities of erosive particulate. Protection from snow and hoarfrost should also be considered through the use of snow hoods and / or some type of anti-icing. In areas subjected to snow or continuous winds, the AAF ASC or PulStar single-stage self-cleaning filter could also be utilised.

COASTAL AND MARINE ENVIRONMENT

This environment, with its airborne NaCl (Sodium Chloride), contributes to hot section corrosion in a gas turbine. The corrosion occurs after Sodium combines with

ENVIRONMENT	Rural Countryside	Coastal & Platform	Large Cities (Power Stations)	Indust (Steel
WEATHER CONDITIONS	Dry & sunny, rain snow and fog.	Dry & sunny, rain snow, sea mist, freezing fog in winter.	Dry & Sunny, rain, hailstones, snow & smog.	Dry an rain, sn hail-sto
TEMPERATURE				
Range °F	-4 to + 86	-4 to +77	-4 to +95	-4 to +
Range °C	-20 to + 30	-20 to + 25	-20 to +35	-20 to
TYPES OF DUST	Dry, non-erosive.	Dry, non-erosive, but salt particles exist; corrosive mist.	Sooty-oily, Mat be erosive, also corrosive.	Sooty- Erosiv May b
DUST CONCENTRATION				
mg/m3	0.01 - 0.1	0.01 - 0.1	0.03 - 0.3	0.1 - 1
gr/1000ft	0.004 - 0.0436	0.004 - 0.0436	0.01 - 0.13	0.043
PARTICLE SIZE	0.01 - 3	0.01 - 3 (Salt 2 - 10)	0.01 - 10	0.01 -
EFFECT ON G.T.	Minimal.	Corrosion.	Fouling Sometimes erosion and fouling.	Erosio Somet

NOTES: ** In emission areas of chimneys* *** During severe sand storms* **** At track level and/or during sand storms.*

Sulphur and / or Oxygen during the combustion process, and is deposited as a liquid flux on the hot section components.
Other metals, primarily Pottasium, Vanadium and Lead, either as Sulphates or Oxides will also contribute to the hot section corrosion. There are two primary sources of these metals, the inlet air and the fuel. Maximum allowable concentrations of these metals in the inlet air may be calculated, using the concentrations in the fuel, but most manufactures are currently using 0.01 PPM of Sodium Chloride (0.004 PPM of Sodium, Na) as an air quality specification downstream of the air filtration system.

COASTAL-LAND BASED INSTALLATIONS

Sodium Chloride is usually present in the air in the form of a salt nuclei of about two micron equivalent diameter. It can be either wet or dry.
For equipment selection, consideration of a low velocity system is necessary. The AAF low velocity system uses fibreglass pads as the non-entrainment coalescer.
Provision for adequate drainage is a must. In areas of heavy rainfall, the addition of weather hoods should be considered. The final filter should be the DuraCel/DuraVee Grade 90 series. Protection of the filter house against corrosion by epoxy paint or perhaps all stainless steel construction is vital.

OFFSHORE INSTALLATIONS

Because of their great height above water, turbine intakes located on offshore platforms can be treated the same as coastal installations. The need for protection from dry salt particulate during periods of lower humidity (below 75% RH) requires a DuraCel / DuraVee Grade 90 series final filter.
Experience has shown that installations utilising a high velocity, mechanical vane separator system would also require a DuraCel/DuraVee Grade 90 high efficiency filter to prevent by-passing of dry salt particulate and leaching.

MARINE INSTALLATIONS

The intake air system may encounter large quantities of sea-water (depending upon height of intake above sea level) and large water droplets with salt in solution.
In these installations, the high-velocity vane separator system could be used. If the intake will operate under conditions of lower humidity, a DuraCel/DuraVee Grade 90 final filter should also be considered.

l Areas orks)	Deserts (Sandy Storms)	Tropical	Arctic	Mobile Installations
unny, w, es, smog.	Long dry sunny spells; high winds; Sand & dust storms; some rain	High humidity, tropical rain, insect and mosquito swarms	Heavy snow, high winds icing conditions, insect swarms in summertime in some areas	All possible weather conditions
5	+23 to +113 -5 to +45	+41 to +113 +5 to +45	-40 to +41 -40 to +5	-22 to +113 -30 to +45
y; orrosive.	Dry, erosive in sand storm areas, Fine talc-like in areas of non-sand storms, but dusty ground	Non erosive May cause fouling	Non erosive	Dry, erosive sooty-oily corrosive
36	0.1 - 700 0.04 - 306	0.01 - 0.25 0.004 - 0.10	0.01 - 0.25 0.004 - 0.10	0.01 - 700 0.04 - 306
)*	1 - (500)**	0.01 - 10	0.01 - 10	0.01 - (500)***
es & fo g.	Erosion, corrosion	Fouling	Plugging of air intake system with snow and ice.	Fouling, erosion, corrosion

LARGE CITIES

If the dust concentration is in the order of less than 0.1 milligrammes/cubic metre (0.04 grains/thousand cubic feet), the Roll-O-Matic filter with gel impregnated media will protect the axial compressor against the erosive dust particles. The Roll-O-Mat media usage rate will also be acceptable.

If the dust concentration is higher than 0.1 milligrammes/cubic metre (0.04 grains /thousand cubic feet), the Dust Louvre inertial separator could be the first choice. If protection against the fine-sooty-oily dust particles which cause compressor blade fouling is required, then the first stage filter system described above should be followed by the DuraCel/DuraVee series filter. It should be pointed out however that the more usual solution is to clean the compressor by washing techniques or the introduction into the intake air stream of an abrasive material (walnut shells). The gas turbine manufacturer will give definite recommendations as to methods of cleaning versus high efficiency filtration.

In the event of known corrosive particulate compounds in the atmosphere, the DuraCel/DuraVee filter is a good solution.

TROPICAL ENVIRONMENT

Two things are essential in this environment - protection from torrential rains and insects. Weather hoods in addition to weather louvres may be required in areas where rains can frequently exceed 120mm per hour. Small mesh (1.5mm^2) low velocity (1m/s) insect screens should be utilised.

Roll-O-Matic or AMER-kleen M-80 filtration will provide adequate protection.

INDUSTRIAL AREAS

In the industrial environment, the widest possible variations in dust concentration and particle types may be expected. Erosive, fouling, and corrosive dust are seen. The final stage filtration should be the DuraCel/DuraVee series with a prefilter stage using the AMER-kleen type M-80 pad. Generally, dust concentrations will be too high for the Roll-O-Matic filter.

Where dust concentrations are in the order of 0.125 milligrams/cubic metre (0.05 grains/thousand cubic feet), the Dust Louvre inertial separator should be used to extend the life of the final and prefilter stages. In very dirty areas such as foundries and steel mills, the use of the PulStar or ASC single-stage self-cleaning barrier filter would be a good choice. The low maintenance requirements on the PulStar or A.S.C. should more than offset the slightly higher initial installed cost.

Careful consideration of intake orientation should be exercised since dust concentrations can sometimes be minimised. Weather protection and/or anti-icing should be considered if climatic conditions warrant.

Special materials of construction or epoxy coatings frequently are required to protect the filter housing.

DESERT LOCATIONS

If possible, the air intake should be located about 8 metres (26 feet) above ground level so as to prevent the ingress of dust particles stirred by small gusts of wind or vehicular traffic in the area. Aggregate dust particulate, ie. Silica and Sodium Chloride is common in desert locations, specifically the Middle East. Removal of the salt is necessary if satisfactory life of gas turbine hot gas path parts is to be achieved. In addition, airborne particulate concentrations are very high (> 500 milligrammes/m^3) during the sandstorm season. Experience shows that high dust concentrations remain in suspension many hours after the initial dust storm.

The final stage of filtration should be the DuraCel/DuraVee series cartridge filter which offers a high efficiency, large dust holding capacity and is non-leaching, ie. retains the collected salt during varying humidity conditions. A prefilter stage, utilising the AMER-kleen M-80 pad, preceded by a first stage of Dust Louvre inertial separator offers an excellent system.

The ultimate intake filtration system for the desert

environment however is the AAF PulStar or A.S.C. single-stage self-cleaning barrier filter. The PulStar and A.S.C. systems have the ability to continue to operate during periods of dust storm conditions by self cleaning itself thus eliminating the need for element replacement or activation of bypass doors.

ARCTIC ENVIRONMENT

In addition to the snow and ice one would expect in the Arctic region, summertime can bring blowing dust and swarms of insects. Therefore, the recommended filtration system would be anti-icing system, weather hood, Dust Louvre inertial separator, and removable insect screens.

An alternate would be the PulsStar or A.S.C. single-stage self-cleaning barrier system which can handle hoarfrost, snow and summer dust.

MOBILE INSTALLATIONS

Gas Turbines have been installed in a wide range of trucked and tracked vehicles such as:

- Mobile Generators
- Military Vehicles
- Crawler Tractors
- Rock Crushers
- Wheeled Scrapers
- Mining Trucks
- Over-highway Trucks

Helicopters and Hovercraft present further special problems. Each individual application must be looked at in depth, prior to making recommendations.

Special Considerations in designing the air intake package

INLET WEATHER PROTECTION

The best possible protection against the ingress of rain, snow, sleet and hail, is a large weather hood so designed that the air enters vertically upwards.

The more usual protection however is by weather louvres. To be effective against the ingress of rain, the louvres should always have vertical blades of at least 2.1/2 Pass design, and generous drainage points.

HOUSING DESIGN

The Intake Filter Housing design depends upon many factors such as:

- Volume or air and type of filters.
- Wind load.
- Snow load.
- Negative pressure inside housing.
- Installation; whether ground level or above ground level.
- Acceptable dimensions for transportation to the job site.
- What lifting facilities will be available on the job site.
- Protective finish against corrosion.
- Location of blow-in doors.
- Location of one or more air outlet connections for gas turbine combustion air and possibly additional air required for other purposes; such as alternator cooling, etc.
- Can the Intake Silencer be installed within the filter housing.
- Will filters be installed in one side, two sides, three sides or all four sides of the housing.
- Will space be required for possible installation of an additional filter stage at some future time.

UNFILTERED AIR BY-PASS DOOR

Some turbine manufacturers require that an unfiltered air by-pass door be provided on the gas turbine inlet. AAF provides this option if required.

EVAPORATIVE COOLER

Due to its design the turbine output is affected by the temperature of air entering the compressor. When the temperature goes above the design point (international rating conditions 15°C and 1.013 mbar), there is a loss of horsepower. Correspondingly, when the temperature goes below the design point, there is a gain above rated horsepower.

On installations where the inlet temperature to the gas turbine exceeds the design operating temperature, an AAF AMER-kool II Evaporative Cooler can be installed to lower the dry bulb temperature and increase engine efficiency resulting in increased usable horsepower or corresponding fuel savings and increased engine life. As a side benefit, evaporative cooling can reduce Nitrogen Oxide emissions.

AAF can demonstrate that the addition of an AMER-kool II evaporative cooler will have a payback period of a few short months and significant fuel savings thereafter.

INTAKE ANTI-ICING

Turbine intake icing can occur from condensate when the inlet air drops below the dew point or precipitation icing which occurs when free moisture strikes surfaces that are at or below the freezing point. Ice fogs and hoarfrost are examples of icing.

When ambient conditions are at the freezing point, either condensed water or precipitate moisture in the form of rain droplets, snow, or ice can freeze and build up on the inlet filter, silencer, screens, plenum walls, turbine inlet guide vanes, and any other portion of the inlet system which is at or below freezing. Although a turbine can ingest small quantities of moisture without damage, collection of ice on the inlet surfaces and the possibility of ingesting large quantities of ice is a major operational problem. Consequently, some type of inlet temperature control to prevent icing is recommended.

Inlet air heating can be accomplished by:

1) Introducing compressor bleed air into the inlet. This results in a loss in efficiency or horsepower.

2) Direct injection of the hot exhaust gases which, although a free source of heat may cause turbine fouling.

3) Indirect heating of the intake air using exhaust gas through an inlet heat exchanger.

AAF can design and supply the most effective system to suit each installation.

SILENCING

After the criteria for acceptable noise of the air intake has been established, the selection of a silencer is not difficult.

The sound power level can be obtained from the turbine manufacturer, as this is the measure of the noise spectrum emitted from source of the intake of the actual compressor.

It is then a matter of determining the amount of attenuation needed to reduce the noise in each octave band to the sound pressure level desired at the design distance from the noise source, allowing for the attenuation from dispersion due to this distance.

AAF supplies exhaust silencers as well as intake silencers specifically designed to meet the site and turbine requirements.

ENCLOSURES

Enclosures for the gas turbine are generally required to provide an acoustic barrier, fire protection, turbine cooling, and weather protection.

Each enclosure is designed and manufactured to suit the individual requirements of the machine/sound source being enclosed. It can have a simple panel design or be a heavy integrated housing with fire ratings up to A60, manufactured in a range of steels, including plastic coated, and aluminium.
Additional features can include lifting beams, lighting, fire and gas detection, and protection systems.

An alternate solution is to use heavy plate construction with fibreglass packed walls and ceilings and perforated sheet inner panels.

COMPLETE GAS TURBINE PACKAGES

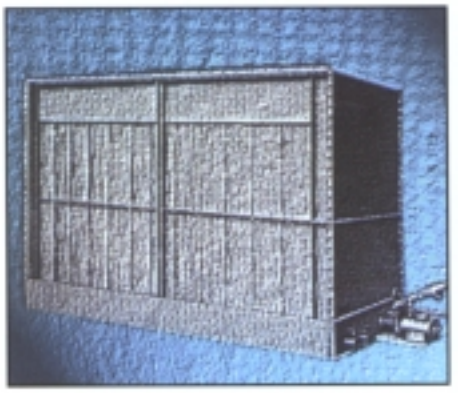
AAF provides complete gas turbine package systems including intake air treatment and silencing, enclosure, and exhaust silencing.

To aid the design engineer, AAF has developed a gas turbine checklist which concisely lists all of the criteria necessary to design a complete turbine package.

The checklist and additional technical information on complete turbine package design is available from AAF.

Recommended AAF filtration equipment

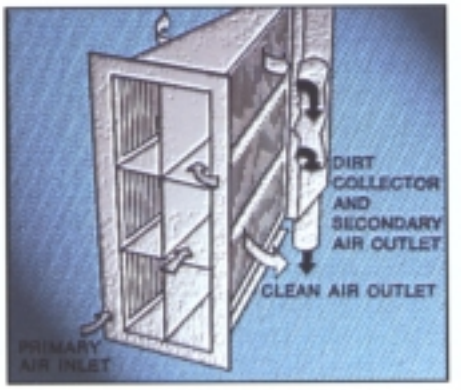
AMERKOOL II EVAPORATIVE COOLER



Evaporative cooling unit designed to humidify the air for optimum turbine performance.

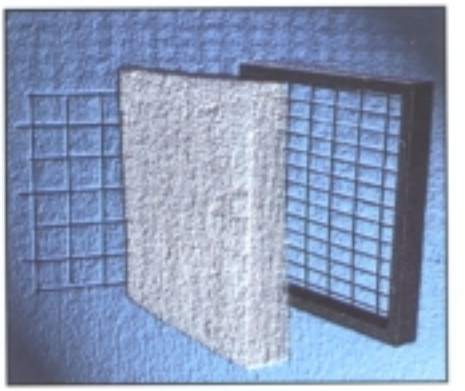
Water is introduced from a spray pipe overhead, dripping down through a distribution pad and spreading out along the top of the media pack. The water then travels downward through fluted channels in the media, flowing toward the air-entering side of the unit. Incoming air enters the media face, making contact with the wetted surface.

DUST LOUVRE INERTIAL SEPARATOR



The Dust Louvre, a self-cleaning unit operating on the principle of inertial separation, is designed for the removal of solid dust particles. It is most suitable for heavy atmospheric dust concentrations.
Dust Louvres are often used as a pre-cleaner for more efficient secondary filters.

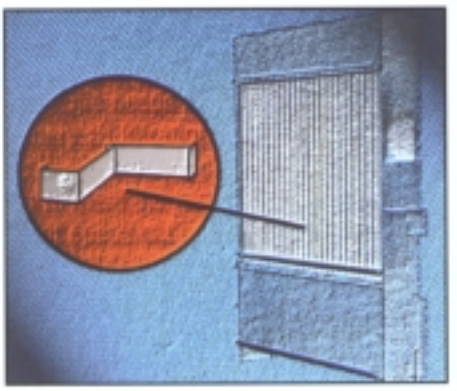
GLASS FIBRE FILTER PADS M-80, M-81



A series of specially designed, throw-away filter pads available in several efficiency ranges. Pads are held in place by an easy access, metal retaining frame.

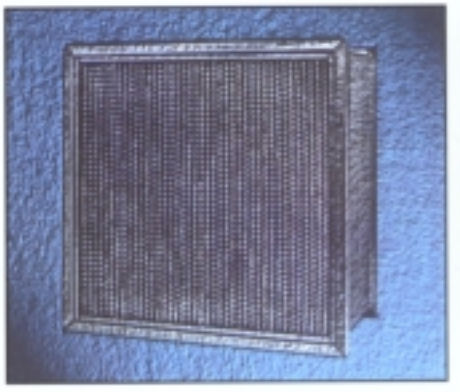
The M-81 pad is used for mist elimination. It utilises a waterproof bonding agent to ensure its continued performance.

WEATHER LOUVRES



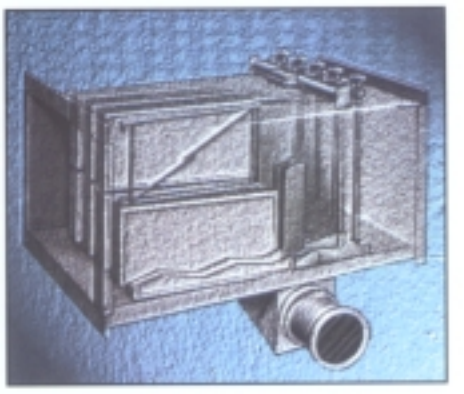
Unique 2.1/2" pass design insures maximum protection against virtually all weather conditions. Units can be furnished in any configuration; can be permanently installed or hinged for front access to the filter.

DURACEL FILTER



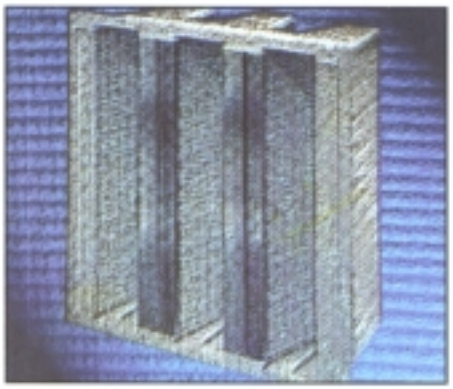
A series of medium and high efficiency disposable filters. This filter features low initial resistance, high dust holding capacity and a choice of efficiency ranges.

AUGMENTED SELF-CLEANING INTAKE SYSTEM



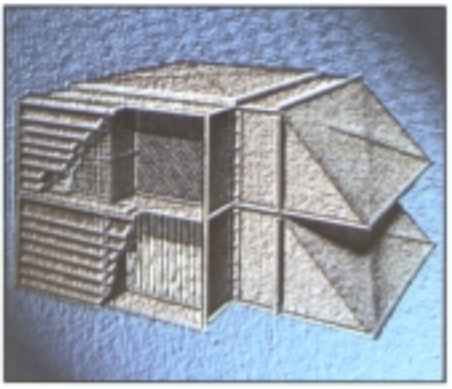
A revolutionary new concept in inlet air filtration for gas turbines. It combines inertial separation with self-cleaning air filtration in one compact package.

DURAVEE BARRIER FILTER



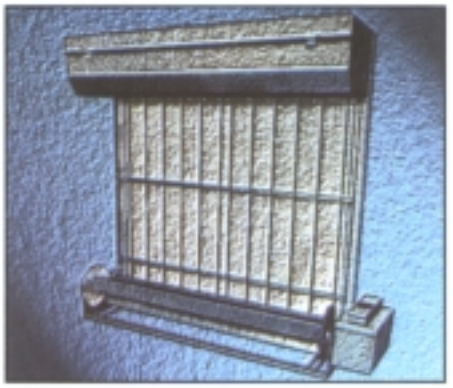
State of the art barrier filter featuring mini-pleat, V-bank media pack design. The mini-pleat media packs are bonded inside the cell sides forming a completely unitised filter that withstands unusually high velocity and turbulent air flow without pack shifting or pleat deformation. DuraVee filters offer lower resistance and higher dust holding capacity than standard barrier filters. Available in 90% and 60% efficiencies.

UF-H FILTER/SILENCER



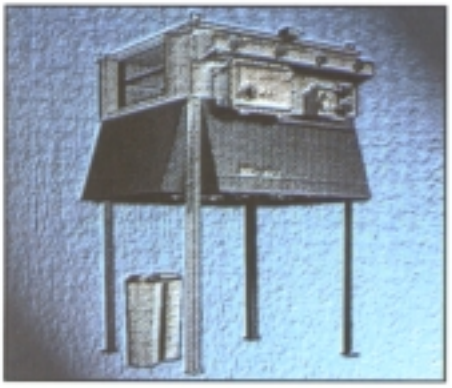
The versatile UF-H Filter/Silencer is designed to house any 24" x 24" filter and/or pre-filter combination. It is ideal for turbine ventilation or intake filtration. Installation of any unit filter or pre-filter combination in one universal housing is made possible by an unique, adjustable locking mechanism which provides positive sealing as well as quick release for filter service or replacement.

ROLL-O-MATIC FILTER



An automatic renewable media filter in which the glass fibre filtering media is automatically fed into the air stream and re-rolled after it has accumulated its dust load. The glass fibre curtain moves intermittently at predetermined levels depending upon dust load.

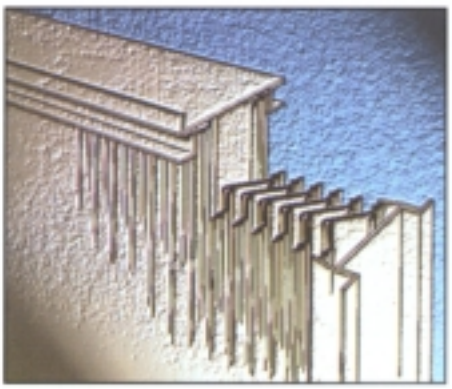
PULSTAR SELF-CLEANING HIGH EFFICIENCY FILTRATION



The AAF Pulstar intake air filter is designed to clean intake air for smooth flow machines. It provides a continuous flow of filtered intake air, eliminating the necessity of short-term filter changeout due to high atmospheric dust load conditions.

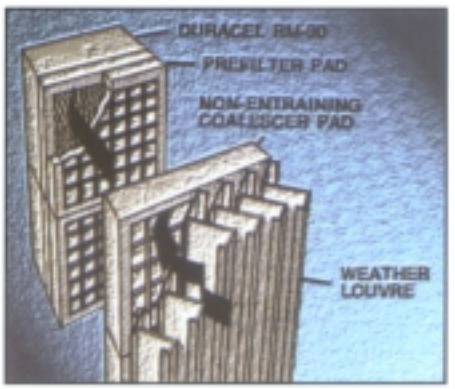
The AAF Pulstar air filter system, because of its modular arrangement, is adaptable to a wide variety of applications.

AMERVANE VI HIGH VELOCITY WEATHER LOUVER



Heavy duty, highly efficient moisture eliminator. Provides excellent free moisture removal at velocities up to 6m/s

SPE-3 LOW VELOCITY WET AND DRY SALT REMOVAL SYSTEM

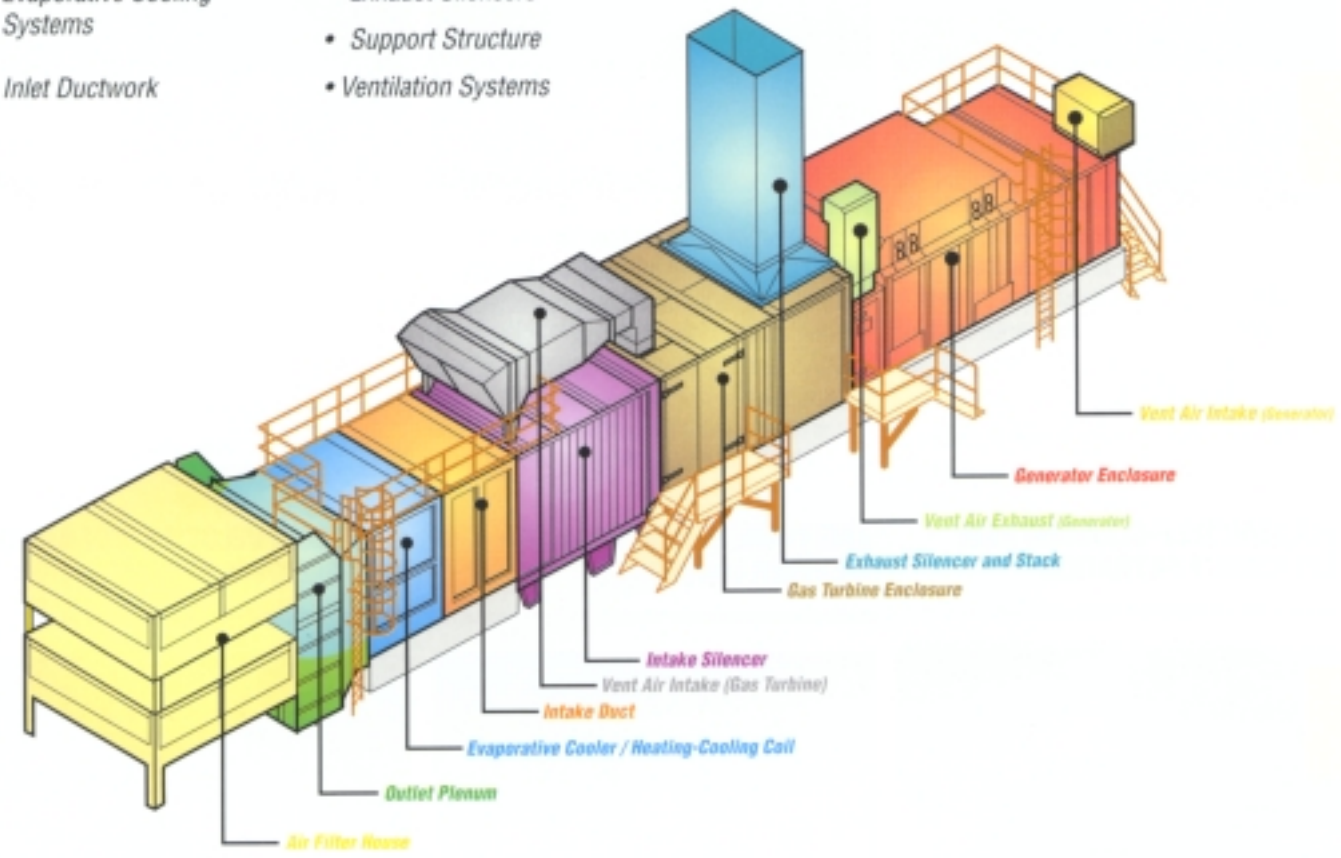


Multi-stage, low velocity system consisting of a weather louvre separator, non-entraining coalescer pad, pre-filter and a Duracel high efficiency dry filter.

OUR TOTAL SYSTEM CAPABILITY AND PRODUCTS

Extensive experience in the design and application of gas turbines and other high-performance rotating machinery, plus our global manufacturing capabilities, position us uniquely to deliver total systems and top-quality products including:

- *Inlet Filtration*
- *Chilled Water Coils*
- *Anti-Icing Systems*
- *Evaporative Cooling Systems*
- *Inlet Ductwork*
- *Inlet Silencers*
- *Expansion Joints*
- *Acoustical Enclosures*
- *Exhaust Silencers*
- *Support Structure*
- *Ventilation Systems*



We have a policy of continuous product research and improvement and reserve the right to change design and specifications without notice.

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