Fundamentals of Cooling Systems Filtration

Introduction

BAC recommends that an effective filtration system be installed on all cooling systems for several reasons.

Proper cooling tower filtration:

- Extends the life of your cooling system and offers a quick return on the investment (payback period usually 12-18 months)
- Reduces the risk of Legionnaires Disease outbreaks
- Maintains optimum heat transfer efficiency in heat exchangers
- Aids in optimization of water treatment equipment
- Reduces expenses for chemical treatment programs, maintenance and cleaning costs, downtime

The following article on filtration is a brief review of different technologies and approaches to cooling tower filtration, including the advantages and limitations of the most popular filtration systems that are used in both open and closed loop cooling systems.

The Fundamental Goals of Fluid Filtration

When considering what type of filtration provides the best value for your cooling system it is important to review the Fundamental Goals of Fluid Filtration, which include:

1. ***WHAT*** are the solids you want to filter out of the fluid?
   This is specified in terms of:
   - Size (measured in microns)
   - Weight of the particles (measured in specific gravity)
   - Shape
   - Volume
2. ***WHERE***, or at what point in the system do you want to filter these particles, and what effect will a given filtration technique have on the rate of flow, pressure losses, and other characteristics of the fluid being filtered? Tied in with these considerations is the basic question of which components of the cooling tower system needs the protection that the chosen filtration provides?

It is critical that the fundamentals of filtration are addressed to insure that the expected results are achieved. Let’s start with the solids.

Fundamental #1: The Solids

Particle contamination of evaporative cooling loops can be created by a variety of sources, including air-borne entry, make-up water, corrosion by-products, and precipitated mineral development. Contamination of closed loops is typically from construction or corrosion by products. For both open and closed loops the particle matter commonly fouls heat exchangers reducing heat transfer efficiency, causing excessive shut-down/cleaning routines, and posing health and safety concerns. It is important to first identify and define the particle contaminants before applying a filtration technique to effectively remove those contaminants. It is also equally important to select a filtration technique with an understanding of its proper placement, sizing and solution potential.

Particle analysis must include an awareness of not only what type of particles are in the cooling water, but also what particles are most responsible for the fouling and/or lost efficiency of the heat exchanger. An understanding of particle type will greatly determine the proper type of filtration to apply. Understanding the issue of particle size will determine the level of filtration necessary to achieve the desired protection of the heat exchanger, AND address any health and safety issues that may be involved. In essence, it is not always critical to remove the very finest sizes of all types of particle matter in order to assure proper protection, and safe operation of the cooling water system and heat exchangers.

With the knowledge of what contaminants must be filtered to achieve reliable and safe cooling system operation, a review of the popular filtration methods helps identify the proper devices for a given application. Then, using an objective set of selection criteria, the most appropriate filtration system can be determined. Performance and price are obvious issues, but there are several other key factors to consider when the goal is long-term overall savings.

The techniques for filtering cooling water each promise a different level of success as it relates to protecting heat exchangers. Understanding the basic installation scheme for each technique unveils that technique's ability to remove particle contaminants. Over the years, experience and performance have produced a comparative view of various techniques that can help grade the potential solution capability of each technique. An in-depth review of the techniques will identify advantages and limitations.

Settleable solids, such as sand, silt, grit, scale, rust and precipitated minerals are certainly problematic, since they are large enough to clog nozzles and small orifices and heavy enough to settle in tower basins and remote sumps. These solids are routinely present in sufficient concentrations to create problematic conditions throughout a cooling tower system.

Suspended particle matter, such as leaves, grasses, cottonwood seeds, bird feathers, insects, and organic matter in excess concentrations can clog nozzles and small orifices shutting off flow in the system. This type of particle is also of concern to tower fill. Since these contaminants typically do not settle, it is unlikely that they will create problems in tower basins or remote sumps, but potentially cause problems downstream at the heat exchangers.

Particle size is an area for debate within the whole process of particle analysis. One view is that contaminants as small as 0.5 microns or less are not only the predominant numerical contaminants in cooling tower water, but also most responsible for the majority of cooling tower problems. The other view is that ultra fine particles (defined as particles smaller that 5 microns – about the size of blood cells) and particles not visible to the naked eye (40 microns – the size of a grain of talcum powder or the end of a human hair) are not the major source of fouling and increased health risks in cooling systems. In determining what filtration system is best for your system, BAC recommends that a common sense approach be utilized and take into consideration:

1. Particles that are capable of plugging orifices and restricting flow must be removed.
2. On the health and safety side of this issue, the United States Center for Disease Control (direct communication with Dr. Barry Fields, CDC) recommends that there be less than 1/16th inch of dirt settling in a cooling tower basin in order for the system's water treatment/biocide to work effectively and come in contact with the bacteria in the system.
3. The Water Quality Association – an authority on drinking water standards in the U.S. recognizes that any contaminants below 5 microns in size are most commonly identified as bacteria, a contaminant that is not removed by filtration, but by disinfection.

Particle volume should also be considered. The chart below offers a comparative and hypothetical example, taking a sample of one trillion particles, with given portions of that sample in each of several particle sizes. As can be seen, if 15% of the total numerical count of particles is greater than 10 microns, those 15% represent over 99% of the total volume. In an actual cooling water loop, there may be many times this amount, but the relative ratio is still valid and important to consider in terms of which contaminants to be most concerned about. This fact should be considered when determining the particles that are capable of fouling a heat exchanger's small orifice, clogging a nozzle or accumulating in a cooling tower's fill, basin or remote sump preventing the system biocide from reaching the bacteria.

Table 1 – Particle Size vs. Volume

Size of Particle	Quantity of Particle	Total Volume
0.45 microns	212.5 billion particles	0.006 cubic inches
1 micron	212.5 billion particles	0.007 cubic inches
3 microns	212.5 billion particles	0.190 cubic inches
5 microns	212.5 billion particles	0.890 cubic inches
Sub-total:	**850 billion particles**	**1.088 cubic inches**
10 microns	37.5 billion particles	1.3 cubic inches
25 microns	37.5 billion particles	18.5 cubic inches
50 microns	37.5 billion particles	150.1 cubic inches
75 microns	37.5 billion particles	504.1 cubic inches
Sub-totals:	**150 billion particles**	**674.0 cubic inches**

The table above, representing a sample of one trillion particles in a range of sizes, shows that even a relatively small number of particles 10-75 microns in size can represent a very large total volume of particles.

Fundamental #2: Where will the filtration solution be installed and how it will affect other variables
At what location in a cooling tower installation should filtration be installed, and what affect will it have on the operation (and maintenance) of the cooling tower? Although often overlooked, this is a very important aspect of cooling tower filtration. The decision of exactly where to install the filtration solution is often dictated by first identifying what equipment/components needing protection from the contaminants, e.g.: the heat exchangers, the cooling tower basin or remote sump, the tower fill and/or the distribution headers/nozzles.

After making that determination, a second step should assess the costs associated with the problem: increased energy and chemical costs, downtime, cleaning, repairs and/or replacements, outside services, and overtime labor and maintenance. The anticipated costs will become important when the cost of the problem is being compared to the cost of the solution.

In general, there are three approaches (designed by “A”, “B”, and “C” below) to answering the question where to install the filtration solution, and each addresses the problem in a different way and has its own distinct value and benefits.

APPROACH A: Full-stream filtration

With full-stream filtration, the filter is usually installed at the cooling system pump/s discharge, prior to the heat exchangers/chillers. The filter is sized according to the full flow of the pump, filtering all the water that passes on to the heat exchangers/chillers – which is the primary value of this approach. It is estimated to increase the operating cycle of the heat exchanger by ten times before servicing requirements appear (based on experiences with users who have kept good before and after records).

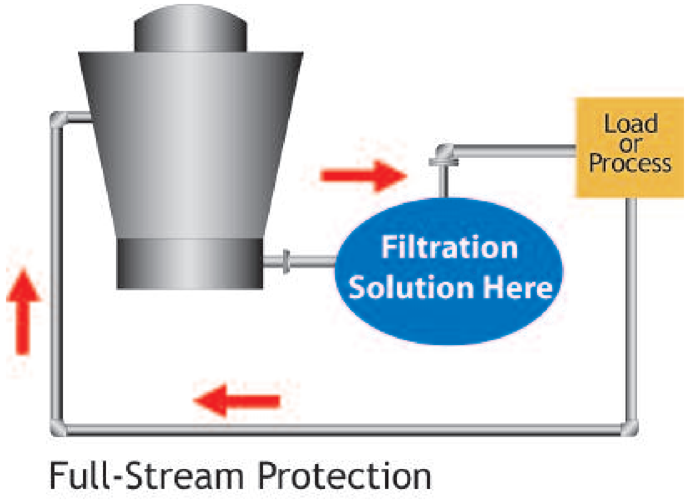


Figure 1: Full Stream Filtration

This approach does not directly address the problem of basin/remote sump solids accumulation. Although effective filtration can reduce overall solids concentration, the tower environment itself does attract and create unwanted solids that can settle in the basin and pass on to the heat exchanger. Full flow filtration is most commonly used for new applications where the effect of the filtration system on system head requirements and space can be considered, and not commonly used in retrofit applications.

APPROACH B: Side stream (or slip stream) filtration

A typical side stream filtration diverts approximately 5-20% of the full-stream flow through a filter and back into the full-stream flow prior to the heat exchangers/chillers. The logic of this technique is filtering the water at a rate greater than the anticipated input of contaminants and volumetric system turn-over. Lower side stream percentages are occasionally employed on closed loops, but not usually sufficient on open systems to adequately remove incoming solids. Location (such as near open fields or windy, dusty situations) and seasonal conditions (such as pollen, harvesting or spring blossoming) provide for higher contaminant potential, suggesting a higher percentage of side stream filtration to overcome these conditions.

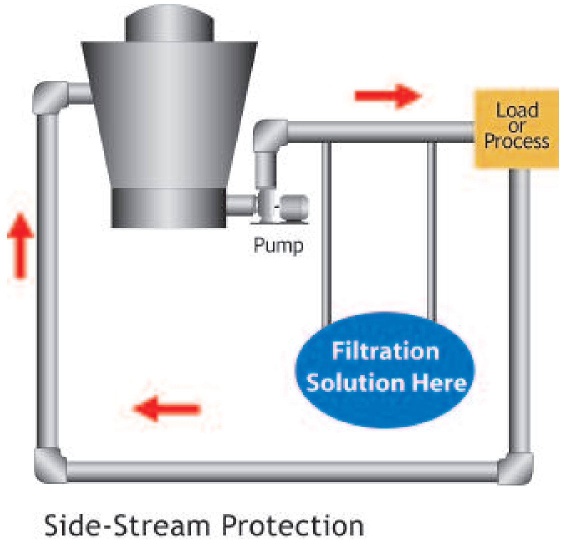


Figure 2: Side Stream Filtration

This approach is estimated to increase the operating cycle of a cooling systems heat exchangers by 3 times before servicing requirements become acute (based on experience with users who have kept good before and after records). This technique is used most often when the full stream flow is extremely high, causing full stream filtration to be financially unfeasible. Like full stream, this technique does not address the problem of solids accumulation in the tower basin or remote sump. Side stream filtration is commonly and effectively applied to both new and existing systems. Care must be utilized when re-directing the side-stream flow back to the pump suction since that reduces the flow to the heat exchangers, or may require an increase in the pump output. With side stream filtration the location of the filtration device is very important to make sure that dirt will get to the filtering system. See Figure 2 for a suggested piping configuration when using the side stream approach.

By using a full flow “Y” or tee and coming off the bottom of a pipe, the solids are more likely to enter a side stream filter increasing the effectiveness of the filtration in removing the solids from the system and reducing “carryover”.

APPROACH C: Basin Cleaning

The filtration is directed specifically at the control of solids accumulation in the cooling tower basin or remote sump. This approach takes control of getting the solids to the filtration system, and virtually eliminates solids build up in the tower basin addressing health and safety issues. The system is very effective at preventing dirt from reaching the heat exchange surfaces. Therefore, basin cleaning is among the most popular and effective filtration approaches in use today.

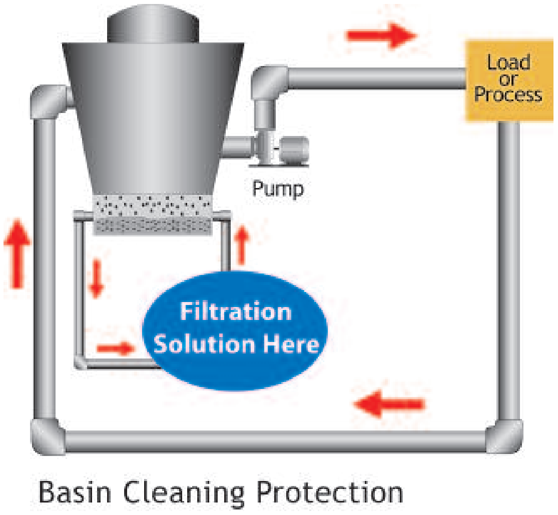


Figure 3: Basin Cleaning

When applying basin cleaning as a means of filtration, water is drawn from the tower basin/sump to the filter package and directly back to the tower basin/sump via a pattern of specialized nozzles (See Figure 4 for an example) to create a directed turbulence of flow designed to influence any settleable particles toward the basin cleaning package’s pump intake. The size of a basin sweeping filtration package is based on the planned area of the cooling tower’s basin or remote sump.

A simple rule of thumb is:

Water Depths	GPM Filtration Required
Less than 3 feet or 0.9 meters	1 GPM per square foot (0.2 m^3/hr per 0.1 m^2)
Greater than 3 feet or 0.9 meters	1.5 GPM per square foot (0.3 m^3/hr per 0.1 m^2)

This technique, despite concentrating its effort to the prevention of basin or remote sump build-up and not directly protecting the heat exchanger, is very effective at keeping dirt from entering the cooling system and expected to increase the operating cycle of a heat exchanger by eight times before servicing requirements become necessary (based on experiences with users who have kept good “before” and “after” records).

Figure 4: Lakos Hydrobooster Nozzles

Unlike the previously mentioned techniques, basin cleaning does directly address basin/sump accumulation. Basin cleaning does require the appropriate use of a venturi-like nozzle system to increase the total flow activity without the need for a high volume pump, thereby keeping equipment and pump energy costs to a minimum. These nozzles and/or eductors increase the flow that passes through them by a factor of 5-6 times, enabling the filter package to use a smaller filter and pump, while still achieving the flow activity necessary to sweep the settleable solids across the basin/sump to the filter package’s pump intake.

An important element to making this approach work effectively is adhering to the flow and pressure requirements (20 PSI or 1.4 bar minimum) of the chosen nozzles in order to achieve the necessary flow to sweep the solids in the basin/sump and prevent troublesome accumulation. Inadequate flow/pressure to these nozzles dramatically reduces their effectiveness and the ability of the system to direct solids toward the pump intake and into the filter. In essence, inadequate flow/pressure results in the same effectiveness as that of a side stream filter.

Popular Filtration Equipment

The advantages and limitations of each of the types of equipment are given in each section. Please See Table 2 – Advantages and Limitations of Popular Filtration Equipment for a quick comparison.

Sand Filters

Widely known, sand filters direct fluid into the top of their tank(s) and onto the surface of a bed of specified sand or other media. As the fluid passes through the bed of sand media, the contaminants are captured within the upper layer of media. The fluid ultimately makes its way downward, passing into some form of underdrain at the bottom of the filter tank and discharging through an outlet pipe or manifold. The cleaning procedure reverses flow upward from the outlet/manifold (either from other filter tanks in the system or from the main system flow), fluidizing the sand media and backwashing the contaminants through the tank’s inlet to a backwash line for disposal discharge. Sand filters are most commonly installed in side stream applications. Care must be taken must be taken before installing in a full flow or basin sweeping configuration because of the potential for interrupted flow during backwash or fouling of the media.

Solids removal – This type of device is most appropriate for lightweight solids, organics and other floating contaminants. Though capable of removing heavier solids, the cleaning/backwash procedure makes it very difficult to rid the sand filter of these solids which may result in a residual build-up and an increasing pressure differential across the filter or excessive backwashing frequency. When specified for removing very fine solids, sand filters must either be oversized to reduce the flow rate per-square-foot or the sand media must be upgraded, adding both cost and higher pressure loss through the filter.

Flow range – The total surface area of a sand filter's media bed and the specified flow rate per-square-inch (20 GPM/sq ft is typical) dictate the size (diameter) and/or quantity of tanks in a sand filter system. Through some makers use only one large tank, others use multiple smaller diameter tanks. Unlimited flow range capability is offset by the logistics of the size and/or configuration of the overall sand filter system.

Pressure loss – Pressure loss varies from low (1 PSI typical) to high (11 PSI). A very low pressure loss through a clean sand filter can be rapidly lost in high solids loading applications.

Liquid loss – It is not uncommon to lose hundred or even thousands of gallons of fluid during a backwash cycle. Significant make-up water may also require significant chemical treatment. As a general rule, some sand media is also regularly lost during backwashing, resulting in periodic media replacement.

Solids handling – Solids handling is usually automated as the solids are carried away in the backwash water. Due to the high liquid content during a backwash cycle, solids concentration is not usually practical.

Replacement parts – Typical parts manuals for sand filters number eight or more pages. The moving parts and electro-mechanical hardware for automatic backwashing account for most of this requirement. Sand media must be monitored and periodically disposed and replaced. Improper backwashing can also lead to contaminant build-up in the sand bed, providing the opportunity for troublesome bacteria to breed and/or accumulate. If oils or grease are present in the system, frequent sand media replacement will be necessary and may be designated as hazardous waste, complicating disposal procedures.

Maintenance requirements – Backwashing can be manually initiated or automatic. Manual operation creates the risk that pressure differential may become excessive and disruptive to the system if not performed regularly and at appropriate intervals. Additionally, infrequent backwashing drives the contaminants deeper into the sand bed, making it more difficult to completely backwash the sand filter and resulting in residual build-up, which increases the frequency of backwashing/liquid loss.

Periodically, even when properly monitored, it is necessary to shutdown the system and dispose & replace the sand media. In high calcium (hard water) content waters it is also not unusual for mineral build-up to induce the sand media to become a hardened cake, incapable of backwashing.

Inspection monthly is usually recommended monthly in order to sustain proper operating conditions.

Space requirement – Expect sand filters to demand 10 to 20 times more space than other types of filtration for a given flow rate. Sand filter configurations are also limited for specific ceiling or piping restrictions.

Advantages: Sand filters remove fine and light particles; Improved water clarity; Easily automated; Requires no solids handling; Wide range of particles removed; Effective over a wide range of flows and pressures.

Disadvantages: Prone to changing, or interrupted flow with solids collection; Handling of backwash water volume; Can be maintenance intensive; Heavy, or precipitated solids pack into sand requiring frequent changing of the sand; Space can become an issue; Backwash water volume can be excessive in high solids loading applications.

Separators

Separators use centrifugal action to remove solids that are heavier than water by use of a tangential inlet that starts the centrifugal action. More efficient designs utilize internal accelerating slots to increase the velocity, and then allow for settling in a low flow area necessary for the removal of the separable solids. Separated particle matter spirals downward along the perimeter of the inner separation barrel and into the solids collection chamber, located below the vortex deflector plate. Solids removal performance varies widely depending on the design.

Solids removal – Separators are proven capable of 5-75 micron performance for particles that are heavier than water. Since the tested performance of centrifugal action separators varies widely among different manufacturers, we encourage third party testing to confirm actual performance at flow rates representing particular site requirements.

Flow range – Separators feature individual units for 3 USGPM (0.7 m^3/hr) up to 12,750 USGPM (2895 m^3/hr). Easily manifolded for even higher (or variable) flow rates.

Pressure loss – Separators operate continuously (no fluctuations) at a steady pressure loss of only 3-12 PSI (0.2-0.8 bar). Compare to screens and barrier filters, which build-up to very high pressure losses.

Liquid loss – Separators require no backwashing. Low-flow periodic purging or a controlled bleed technique can achieve zero liquid loss. Selected solids collection options ensure minimum liquid waste and easy disposal/recovery of solids collected.

Solids handling – evacuation of separated solids should be accomplished automatically by the use of an electrically-actuated valve programmed at appropriate intervals and duration in order to efficiently and regularly purge solids from the separator's collection chamber. Solids can also be concentrated by the use of a solids recovery vessel. In a solids recovery vessel, separated solids are continuously purged under controlled flow into a vessel equipped with one (or three, depending on the separator size needed) 1 to 50-micron fiber-felt solids collection bag(s). The bags are then manually removed and cleaned or discarded.

Replacement parts – Separators have no moving parts, and no filter elements or sand media to clean or replace. The purge options (bag filter, or motorized ball valve) for the separator may have replacement parts.

Maintenance requirements – Separators may be purged of separated solids without system interruption. Easily automated for no maintenance routine. No filter cleaning. No duplicate equipment needed.

Space requirements – Separators are compact. Larger models may be specified at low or vertical profile and/or with alternate inlet/outlet configurations to accommodate limited space or piping needs.

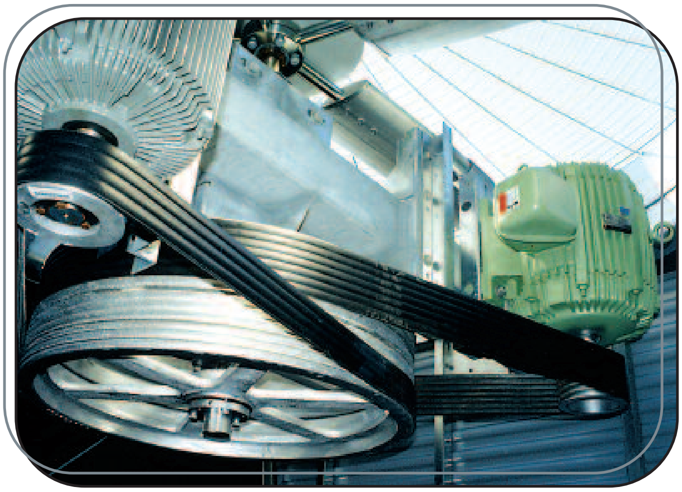
Advantages: Removes a wide range of particles; No moving parts; Very minimal to no maintenance requirements; Constant pressure drop is better for basin sweeping applications; Can be installed full flow with low risk for interrupting flow to the main heat exchangers; Can be automated.

Disadvantages: Primarily removes only solids that are heavier than water.

Table 2: Advantages and Limitations of Popular Filtration Equipment

	Particle Size Removal	Pressure Loss	Maintenance Requirements	Liquid Loss
Sand Filters	Best for fine light particles; avoid heavy coarse particle applications	Low, variable	Back washing; periodic inspection; sand replacement, electro mechanical parts	Potentially excessive
Separators	Fine to coarse inorganics only	Low and steady	Purge components only - periodic inspection/servicing	None to minimal

BALTIGUARD™ Fan System Option for the BALTIDRIVE® PowerTrain*



The BALTIGUARD™ Fan System is an option available on the BALTIDRIVE® Power Train* used on Series 3000 and 1500 Cooling Towers, Closed Circuit Cooling Towers (FXV) and Evaporative Condensers (CXV). It consists of two single speed fan motors and drive assemblies connected to a common shaft. A full size fan motor and drives are installed at one end of the mechanical equipment support and a lower horsepower motor and drives approximately 1/3 the standard motor horsepower, is installed on the other end of the mechanical equipment support. Drives for the lower horsepower motor are sized for approximately 2/3 of design fan speed. This arrangement allows the unit to be operated at either full or 2/3 speed for capacity control and provide significant energy savings during periods of reduced load and/or lower ambient temperatures. The controls and wiring required are virtually identical to those of two-speed, two-winding motors.

BALTIGUARD™ Fan System Provides:

Standby Protection - The BALTIGUARD™ Fan System consists of two independent belt drive systems. Because of this, the BALTIGUARD™ Fan System is the only drive system that provides standby protection in the event of a motor failure. As a minimum, approximately 70% capacity will be available from the low horsepower motor, on a design wet bulb day. On an air conditioning application, the unit can usually meet 100% of the building requirements within 7˚F of the design wet bulb temperature.

Energy Savings – The BALTIGUARD™ Fan System provides significant energy savings throughout most of the operating season. Since the fan drives are sized so that the lower horsepower motor operates the fans at approximately 2/3 fan speed, the switch to the lower horsepower motor occurs more rapidly than with a conventional two-speed motor. With the BALTIGUARD™ Fan System, the switch point to the lower horsepower motor operation can occur within 6°F of the design wet bulb temperature on a typical air conditioning application. This results in significant energy savings since the lower horsepower motor operates approximately 95% of the time.

Reduced Sound Levels – Operation of the BALTIGUARD™ Fan System at the low speed reduces unit sound levels by approximately 6-8 dBA. Since periods of reduced load often coincide with requirements for lower noise levels (such as at night), the BALTIGUARD™ Fan System is a solution to meet the needs of sound sensitive installations.

Capacity Control – The BALTIGUARD™ Fan System can be used in conjunction with fan cycling. This doubles the number of control steps and provides a greater reduction in energy consumption compared to simple fan cycling for capacity control during part-load conditions.

* Patent: This equipment is manufactured under U. S. Patent 4,601,684