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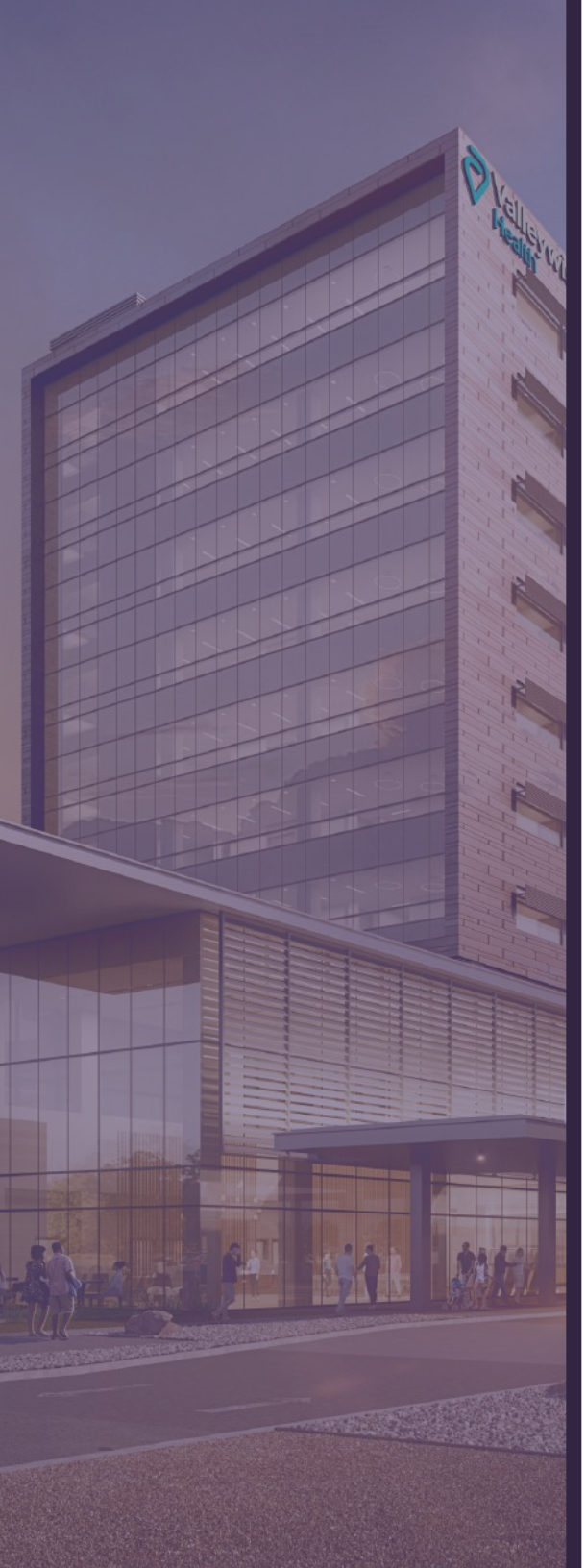

Contents

How solar heat gain affects building design

The SHGC of glazing is a tiny number in a sea of values to consider, but it has broad impacts on HVAC systems, lighting design, the appearance of the building, façade costs and the health and comfort of occupants.

Solar heat gain is a tiny coefficient in a sea of values to consider for mechanical engineers. This number not only drives load calculations, systems selection and shaft sizes, it also can significantly change fenestration costs, procurement and most challenging, the appearance of windows on the building.

As if this number didn't control enough decisions, it also has secondary impacts to occupants' visual comfort, thermal comfort and circadian health. So, what's the difference between 0.27 and 0.23? For solar heat gain coefficient, the answer is entangled with many issues requiring coordination and consensus from team members.

What is solar heat gain coefficient?

It is important to recall the definition of SHGC as distinct from the legacy shading coefficient. SHGC is defined in Equation 1 and includes two terms (see ANSI/NFRC 200-2020).

The first term describes the total directly transmitted solar radiation(τsol) while the second term describes the inward flowing fraction of absorbed and reradiated energy (αi). It is because of this second term, αi that even opacified fenestration assemblies such as spandrel glazing with frit still have a nonzero SHGC due to some small but nonnegligible inward flowing reradiated heat.

$SHGC = \tau sol + \alpha i$

$\tau sol = \tau\lambda,\ 300-2500 = \int_{2500}^{300} E(\lambda)\tau(\lambda)d(\lambda) / \int_{2500}^{300} E(\lambda)d(\lambda)$

Where:

$E(\lambda)$ = Source spectrum, ASTM-G173, AM1.5

$\tau(\lambda)$ = Glazing system transmission

The outdated SC is still often confused with SHGC. While SHGC describes the fraction of total direct and indirect solar energy transmission through a glazing system as compared to the incident solar energy, the SC is benchmarked to a single layer of 1/8-inch clear glass and describes the fraction of transmitted solar radiation as compared to that benchmark glass, which is given a value of 1.0. Note that SHGC and SC are not interchangeable and are approximately related in Equation 3 from ASHRAE Handbook of Fundamentals below.

$SC \approx SHGC/0.87$

How to tune SHGC values

What decisions control the SHGC of glazing? What levers are available to tune its value? High performance glass coatings that are a part of the insulated glazing unit are the most common way to achieve varying levels of SHGC performance. However, it's important to keep track of other factors of fenestration design that impact the total SHGC performance but are controlled primarily by other design parameters such as structural, thermal or acoustic requirements. The number of glass and air gap layers in the IGU, the composition of the glass substrates, the substrate thickness, interlayer films used for lam-

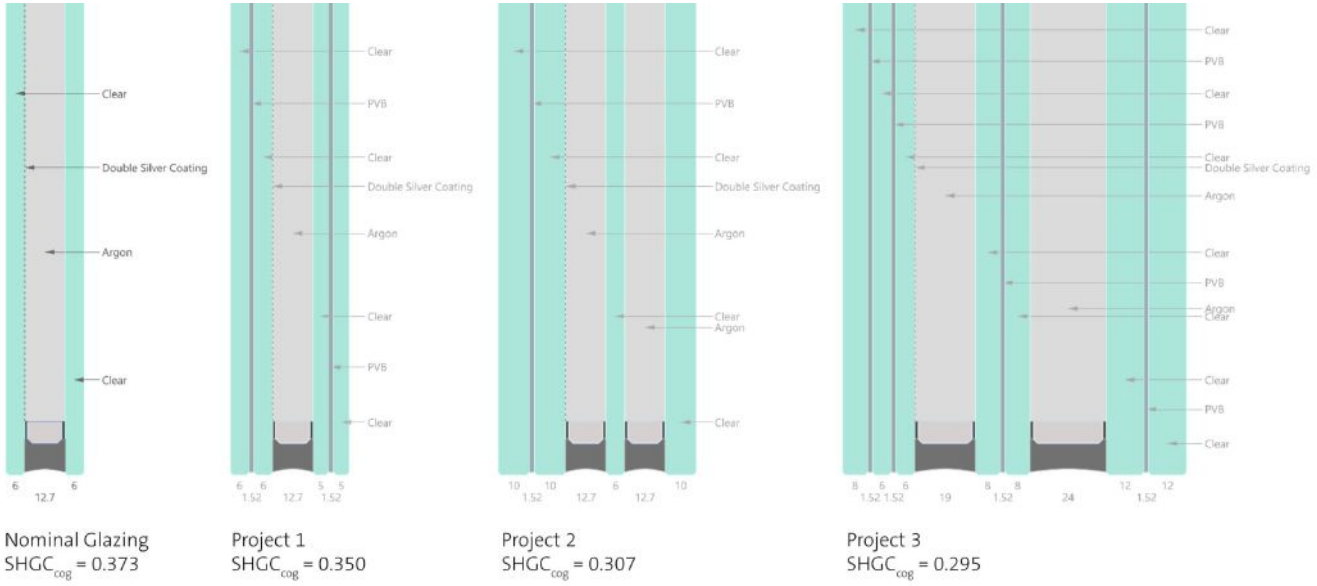

Figure 1: Structural, thermal or acoustic requirements of glazing can significantly modify solar heat gain performance for the same solar control low-e coating. For consistency, this comparison assumes all-clear glass substrates and argon gas fill. The performance of nominal glazing using 1/4-inch glass in a 1-inch insulated glazing unit is typically quoted from manufacturers. Project No. 1 is for a high-rise office with tall floor-to-ceiling glass and high wind loads. Project No. 2 is for a school with large glass sizes, cold winters and lower U-value targets. Project No. 3 is for a hotel next to an airport and has very stringent acoustic requirements. Courtesy: EYP Architecture & Engineering

inates, as well as the window unit size and glass-to-frame ratio all additionally modify the total assembly SHGC.

Figure 1 shows three different IGU build-ups using the same coating but the structural, thermal and acoustic requirements differ significantly for the different projects. The nominal glazing represents a standard IGU and performance often quoted by a manufacturer. Project No. 1 is for a high-rise office building with tall floor-to-ceiling glass and high wind loads. Project No. 2 is for a school in a mixed humid climate with large glass sizes, cold winters and more aggressive U-value targets. Project No. 3 is for a hotel very near an airport

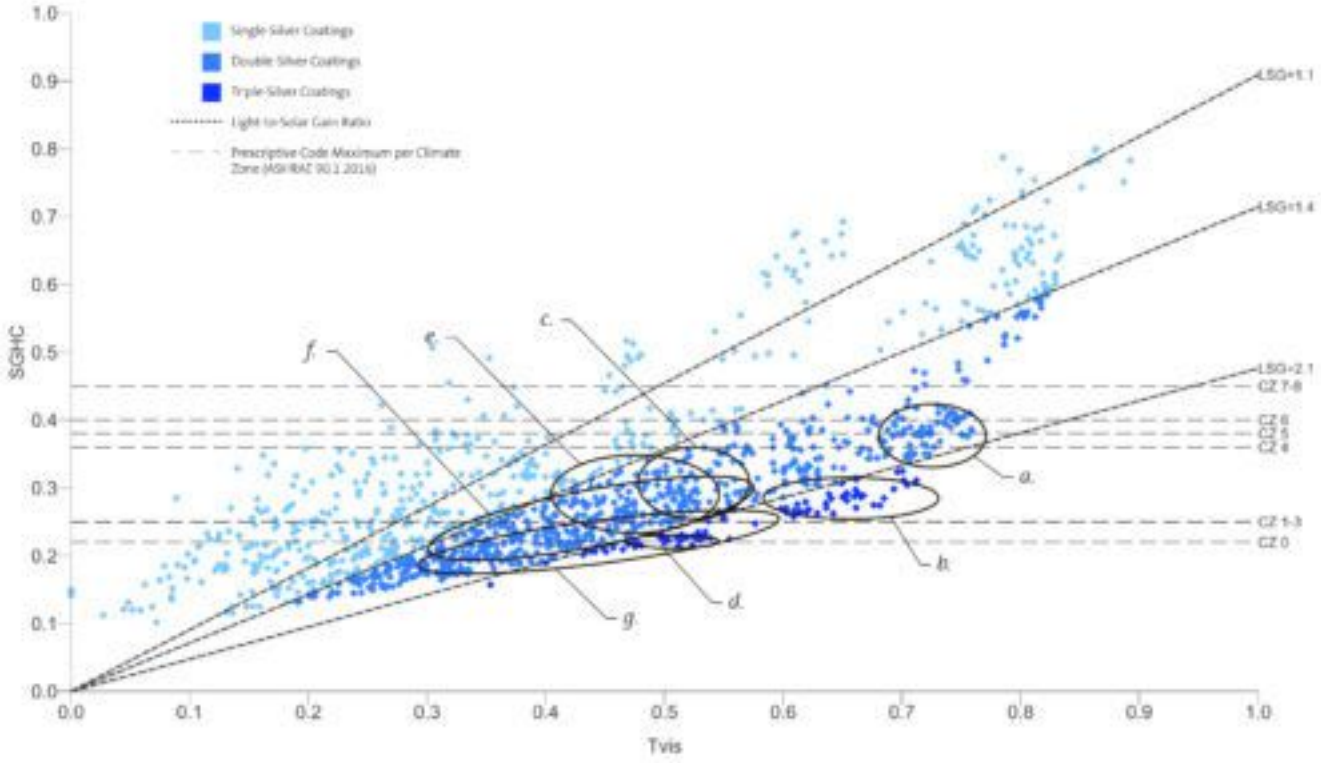

Figure 2: This compares solar heat gain coefficient versus visible light transmittance (Tvis). Group a coatings: standard, color-neutral, double-silver coatings with high Tvis. Group b coatings: standard, color-neutral, triple-silver coatings with high Tvis and reduced SHGC. Group c coatings: dark double-silver coatings with reduced Tvis and SHGC. Group d coatings: dark triple-silver coatings with reduced Tvis and SHGC. Group e coatings: reflective coatings. Group f and g coatings: double- or triple-silver coatings, respectively, applied to various body-tinted substrates. Data source: International Glazing Database. Courtesy: EYP Architecture & Engineering

with stringent acoustic requirements particularly for low-end frequencies. While the same solar control coating is applied to each IGU, the center of glass SHGC significantly varies.

High performance solar control glass coatings made from thin–film sputter depositions of silver-dielectric stacks dominate the market. These coatings

are offered in standardized product lines that react to prescriptive code requirements for SHGC and the desire for maximum visible light transmittance. These product lines are broadly categorized as single- (LSG<1.4), double- (1.4<LSG<2.1) and triple-silver (LSG>2.1) coatings with the light-to-solar gain ratio increasing with the number of silver layers.

The International Glazing Database maintained by Lawrence Berkeley National Laboratory collects measured and validated optical data of the many thousands of coatings available to the architectural market. Analysis of the database and processing through the LBL WINDOW software enables a high-level view of all the glass coatings available to architects and engineers. Figure 2 shows the distribution of coating products by their two primary performance characteristics, SHGC and visible light transmittance (Tvis).

There are a few general product categories to consider and it's important to understand how a SHGC specification will fall into these classifications along with the resulting implications to appearance and daylighting. Single-silver coatings often do not have sufficiently low solar gain without also sacrificing visible light transmittance, so the nonresidential commercial market focus is on double– and triple-silver coatings. Group a. coatings are the most standard double-silver coatings with high visible light transmittance, good color neutrality and low exterior reflection while achieving a SHGC at or near 0.40. These coatings intend to be unnoticeable, with high transparency and excellent color neutrality. Group b. coatings are standard triple-silver coatings with high visible transmittance but with lower SHGC usually around 0.26. The improved SHGC leads to subtle sacrifices in transparency and color neutrality for triple silver coatings. Group c. coatings are darker double silver coatings that sacrifice visible transmittance to reduce SHGC and come with some more noticeable color shifts. Group d. coatings

are a tight cluster of darker triple-silver coatings, again designed to meet increasingly stringent SHGC requirements but with a linear reduction in visible transmittance and more noticeable color shifts.

There are alternate trends to satisfy reduced SHGC specifications that rely on higher exterior reflection coatings that are more mirror-like or rely on applying the any of the group a-d. coatings to a body tinted substrate. Reflective coatings in group e. can be used to achieve good SHGC values around 0.25 to 0.35 and where view into the building is either not important or not desired. Consider also the hazards of higher exterior reflections (in the visible and solar spectrum) on neighboring people, properties and plants.

The second trend mixes coatings with body tinted substrates to again reduce SHGC with mostly linear reduction in visible transmittance. Body tinted substrates come in a number of blue, gray and green hues with a range of (uncoated) transmittance between 0.35 and 0.65. The transmittance of body tinted glass is dependent on glass thickness, so where structural requirements dictate thicker glass in the 3/8– to ½-inch range, there will be a reduction in SHGC and Tvis. Double-silver coatings on body tinted substrates fall in the broad range of group f, while triple-silver coatings on body tinted substates fall in the broad range of group g.

The standard double– and triple–silver coatings that provide the most transparency with good color neutrality have limited SHGC tunability. These coatings can achieve a SHGC around 0.4 or 0.26 in standard configurations. Tuning SHGC with coating selection will then almost always incur a sacrifice to visible light transmittance and color neutrality which have secondary impacts to daylighting, the appearance of the building and human health and comfort.

Impacts to glass procurement and cost

Before examining the implications of a specified SHGC on building and occupant performance, consider the increases to glazing costs and restrictions on procurement. The most basic performance jump from a double-silver to a triple-silver coating results in an average 18% increase in the glass material costs, assuming all other fabrication, heat-strengthening and markup costs are equal. Changing a clear glass substrate to a body tinted substrate results in an average 22% increase in the glass material costs. A change from a high light transmission double-silver or triple-silver to a low transmission or dark version of the coating is usually cost neutral for most glass suppliers.

There can be further restrictions on glass procurement when tuning SHGC to lower values. A vast majority of the many thousands of coatings on the market will not be available to every project due to local market conditions, variations in coating product lines and differences in manufacturer supply integration. Façade fabricators may have a preference for, or an exclusive agreement with, a glass and IGU manufacturer which may limit coating selections, particularly post-award.

Nearly all manufacturers offer a coating product that falls in Groups a-d. Most offer at least one reflective coating in Group e. However, some manufacturers have multiple reflectivity variations. Most suppliers can offer their coatings on a tinted substrate. However, color options can be limited for some and depends on whether the manufacturer's downstream integration includes the float line itself. Vertical integration can also impact supply schedule and cost where manufacturers coat glass to order can satisfy non–stocked options faster and without a premium.

These cost and procurement limitations usually reduce the many thousands of coating

options in the IGDB down to 3 to 5 options for a given project, in a specific local market and with a given façade contractor, which reduces the seemingly smooth gradient of SHGC possibilities into discrete options that are not always in alignment with the basis of design parameters.

Impacts to daylighting

Due to material limitations of silver oxide based solar control coatings, the optimization for maximum visible light transmission and minimum SHGC will always approach a pareto frontier that currently peaks at a light-to-solar gain ratio of 2.48. The drive for lower SHGC values to meet either prescriptive code requirements or beyond code performance targets therefore fundamentally challenges the daylighting potential of a project.

The double- and triple-silver coatings in Group a and b offer the highest visible light transmittance and the best potential to make use of daylight. Most double-silver coatings have a nominal Tvis around 0.72 while most triple-silver coatings have a nominal Tvis around 0.62. The dark shifted double- and triple- silver coatings in Groups c and d offer improved SHGC at the expense of Tvis and daylighting potential, each with a linear decrease from their transparent versions. These darker coating options of Group c and d, together with all other options for reducing SHGC in groups e-g will all sacrifice the maximum Tvis and hinder the daylighting potential. The trade-off between reduced loads from lower solar heat gain therefore requires careful coordination with daylighting goals.

The most common metric to evaluate a spatial and temporal average of the daylighting potential in a building is the spatial daylight autonomy metric used by LEED and other sustainability rating systems and is described in IES LM-83. Figure 3 shows a patient room at the Valleywise Health Medical Center, Phoenix, which has a perimeter

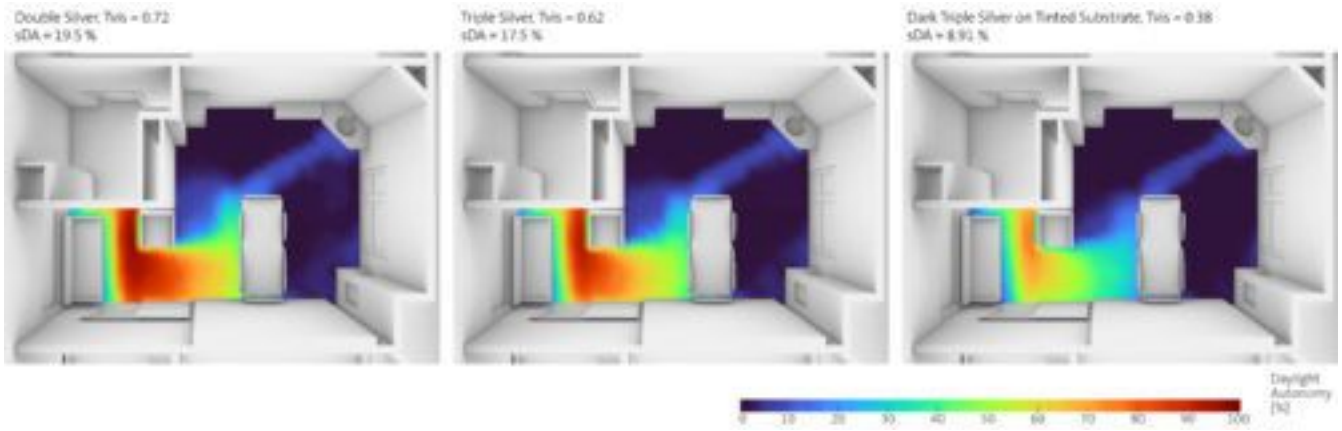

Figure 3: In this example, spatial daylight autonomy is shown for a west facing patient room with decreasing visible light transmittance. The reduced visible light transmittance that accompanies a lower solar heat gain coefficient limits the patient's access to the benefits of daylight. Courtesy: EYP Architecture & Engineering

bathroom and family area with a window to the left. Glass coating options to improve SHGC also decrease the visible light transmission with a resulting drop in spatial daylight autonomy which will limit the patient's access to daylight.

Impacts to visual appearance

Beyond the impact to the daylighting potential of a project, the choice of glass and coating will change the building's exterior appearance. This is one of the most challenging aspects to coordinate because the design intent is not quantitative and not always precisely articulated. The most common trend is for unnoticeable glass that is highly transparent and color neutral such the visual presence of the glazing disappears.

There are some tools available to bring the qualitative design intent of glass appearance in alignment with qualitative metrics of glass and coating properties. The validated, photometrically accurate and open source rendering engine RADIANCE together

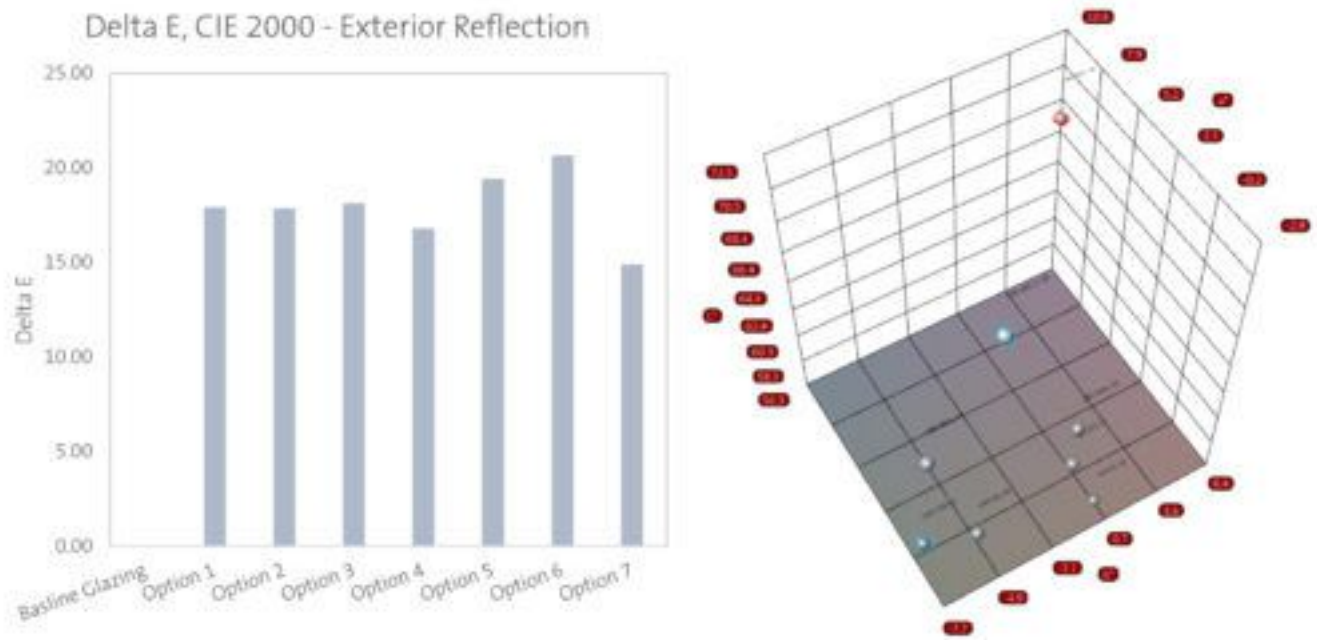

*Figure 5: Calculated here is the delta E color difference of glazing options for a pedestrian bridge at an Orlando hospital campus. The design intent to match the appearance of an existing adjacent building enabled a calculation of the color difference of alternate coating options using delta ECIE,2000. At left, delta E exterior reflected color difference from the baseline glazing option. At right, L*a*b color coordinates of the glazing options with the baseline glazing highlighted in red. Courtesy: EYP Architecture & Engineering*

with GLAZE program offers the best non-proprietary option for simulating glass appearance and uses the IGDB measured spectral data.

A more fundamental calculation is often beneficial to assess the relative difference in color appearance when a desired baseline glass and coating configuration is known, as is often the case when the design intent is to match the glass of an existing building that has been deemed visually acceptable. The delta E metric described in ASTM D2244 is intended to quantify difference between two colors as perceived by the human eye and calculated from measured L*a*b color coordinates.

Color coordinate data is available from the spectral measurements in the IGDB enabling a comparison of specific IGU configurations. Figure 5 shows the calculated delta E color difference of glazing options for a pedestrian bridge at an Orlando hospital intended to match the appearance of the existing building to which it connects but has more stringent solar heat gain performance requirements.

Impacts to visual comfort

Perhaps most critically, the specification of SHGC will indirectly impact the visual comfort of occupants by way of visible light transmittance. For most programs from office buildings to hospitals to lab buildings, the increased interest in daylighting and views must also account for glare and visual discomfort of occupants to productively perform their tasks. Daylight glare probability is the commonly accepted metric developed for indoor lighting scenarios that include daylight from windows.

Figure 6 shows the view from a patient bed at the Valleywise Health Medical Center with false color images of the simulated scene luminance and the DGP rating for that viewpoint. The west facing patient room has challenges with low angle sun in the late afternoon and the visible light transmittance, indirectly controlled by the SHGC specification, impacts the probability a patient will experience visual discomfort when looking toward the family seating area.

It is difficult to satisfy visual comfort at all times with a fixed Tvis of the glazing given the large changes in exterior light levels. For most hours of the day, high Tvis is desired for daylighting; lower Tvis is beneficial when the sun comes into view of the window. When the direct sun is in view a very low Tvis, around 0.01 is preferred and often accomplished with interior window treatments.

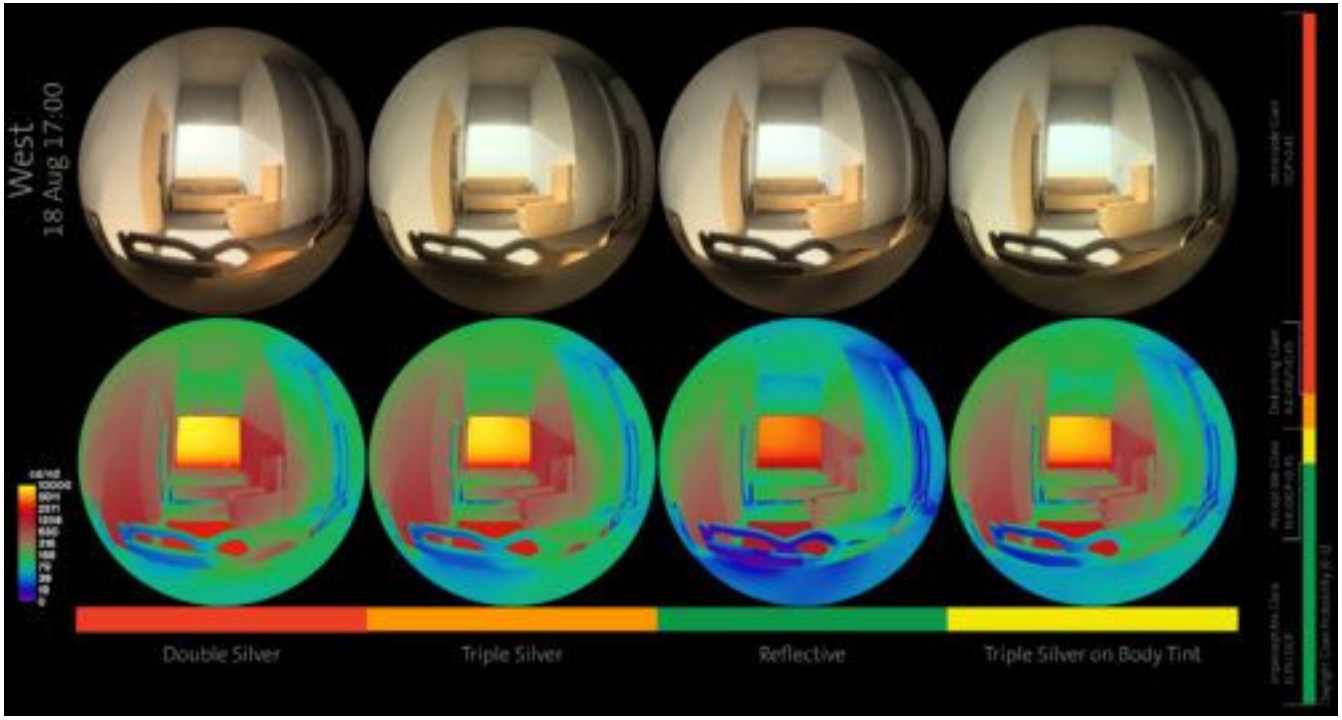

Figure 6: This example shows the daylight glare probability of a view from a west-facing patient bed with varying visible light transmittance (Tvis) specified for the glazing. Double silver coating, Tvis = 0.72; triple silver coating, Tvis = 0.62; reflective coating, Tvis = 0.38; triple silver on a body tint, Tvis = 0.55. Courtesy: EYP Architecture & Engineering

Circadian health

An emerging consideration for daylighting and interior lighting design is for the relationship between the intensity, color, duration and diurnal timing of light in a space and the resulting impacts to occupants' sleep-wake cycles. Rapidly progressing research has shown that human sleep-wake cycles are entrained through a nonvisual system of intrinsically photosensitive retinal ganglion cells (ipRGCs) with a sensitivity that peaks around 490 nm. These blue-sensitive retinal cells respond the intensity and color of light and suppress melatonin to entrain the body's circadian clock. This means not only is the intensity of light as

controlled by the glazing Tvis important for human health, but the color of the light as modified by the glass and solar control coatings can impact occupants' sleep-wake cycles.

In this rendering of the Phoenix-based Valleywise Health Medical Center replacement hospital, the bed tower is positioned with patient rooms facing east and west, requiring special consideration for solar heat gain, daylighting and glare. Courtesy: EYP Architecture & Engineering and Cunningham Group

The SHGC is a deceptively small specification with broad impacts beyond HVAC systems selection, sizing, loads and operational cost. Driving toward lower SHGC targets can significantly change fenestration costs and procurement, the appearance of the building and the daylighting potential of perimeter spaces with further indirect impacts to occupant visual comfort, thermal comfort and circadian health. Because the decision entangles so many disparate issues, it is critical to carefully coordinate the SHGC specification and arrive at a consensus from all team members.

Brandon Andow, Ph.D., AIA, NCARB, EYP Architecture & Engineering, Denver

Brandon Andow *is a senior building performance analyst and envelope specialist with EYP Architecture & Engineering. He is committed to creating practical exteriors that are transformative and meet striding energy targets, all while making occupants happier, healthier and more productive.*

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The Customer

Jim Rearden and Mike Muchow

BioTherm

California-based BioTherm is the exclusive dealer for Raypak boilers to the Controlled Environment Agriculture (CEA) industry. BioTherm has been at the forefront of

developing highly efficient greenhouse solutions since 1980. They specialize in providing climate control solutions for indoor and greenhouse operations from heat and hydro sciences to optimized air.

The Challenge

Indoor and greenhouse farming are growing industries and will continue on this path as consumers look for produce grown closer to where it is sold. But no matter where they are, all plants need just the right levels of light, temperature, moisture and air composition. Greenhouse and indoor farming mean these factors can be dialed in for the best result possible. Many plants require a dose of Carbon Dioxide (CO_2) to increase the efficiency of photosynthesis and maximize growth, and in Fukushima, Japan, it is no different. So, when vegetable facilities there, as part of the regrowth of the Fukushima fallout, sought out BioTherm to find a CO_2 recapture solution, the team at BioTherm got to work. Until this point, the only real solutions for introducing CO_2 into an indoor farm or greenhouse were large bulk tanks or individual CO_2 burners.

The Solution

After experimenting with other Raypak solutions, the introduction of Raypak's XVers® and XVers L Condensing Boiler lines was a game-changer! BioTherm knew that with the right condensing boiler system in place, BioTherm CO_2 Systems can easily be integrated for more customers to achieve the perfect CO_2 levels in indoor and greenhouse operations with clean, safe and dry CO_2.

BioTherm systems harvest CO_2 directly from the boiler's exhaust gases and distribute them uniformly into the growing environment while ensuring other harmful gases are kept at a safe level. With a BioTherm CO_2 System, there is no need for large bulk tanks or individual CO_2 burners.

Raypak's XVers Family efficiently serves two functions in one for BioTherm's customers. First, the boiler provides the hot water needed for successful farming. And secondly, it helps optimize the CO_2 levels in the air. By adding the simple process of collecting the

Benefits

High Efficiency & Clean Burning:
Up to 99% Thermal Efficiency

Air Optimization Friendly:
Burns clean and is easy to get the right amount of CO2 from the exhaust

Wide Range:
From 399 to 3000 MBTUH

Small Footprint:
Well suited for small to large facilities

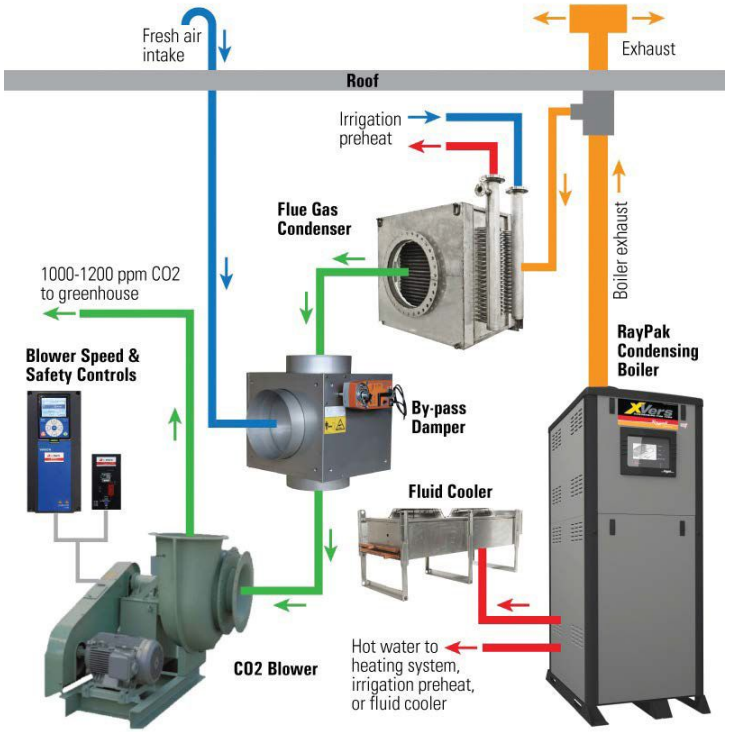
boiler's exhaust, the controllability of the XVers Family allows for a precise level of CO_2 to be introduced into the space for further improved growing efficiency.

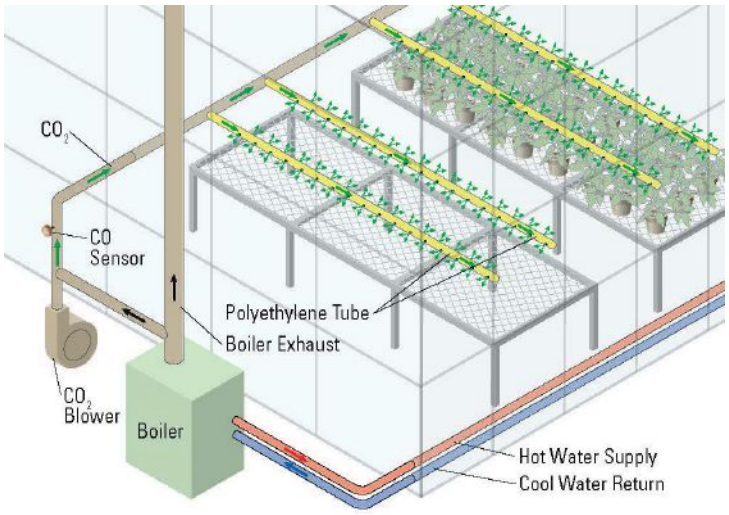
The Installation

The BioTherm CO_2 System features a Raypak XVers Condensing Boiler and secondary heat exchanger paired with BioTherm's Control System and Inline Fan.

The Final Result

"The other options they (cultivators) have are to have a gas provider bring out a giant tank they keep filled to emit the CO_2. Others use CO_2 generator products with an open burner that generates CO_2 but makes it hard to reach the desired parts per million. With our system, they make it on-site and it burns clean. It doesn't take much to get them to the desired set point.





It's a much more economical way to do it and easier logistically without having to get it delivered. It's dry and clean and gives them a big benefit for their buck.

"If they have an existing BioTherm system, this is a simple add on."
— Jim Rearden, President of BioTherm

"BioTherm is impacting this industry and using Raypak boilers to do it!"
— James Kastigar, Regional Sales Manager for Raypak

Here are results from some users of BioTherm's CO_2 System with Raypak XVers Family Condensing Boilers:

- 50% savings on supplemental lighting hours through increased efficiency of photo-synthesis with CO_2 (Lef Farms New Hampshire)

- $90k annual savings for a single site using CO_2 from the Raypak Boiler System (Large, multi-state horticulture operation)

Note: Stated savings are self-reported from BioTherm customers.

To learn more about our High-Efficiency Condensing Boiler Solutions, visit **Raypak.com**

Five applications of computation fluid dynamics motion in three dimensions

Computational fluid dynamics (CFD) can be used retrofitting, estimating hydraulic losses, optimizing flow distribution and more.

Tracking the motion of fluids and understanding how fluids interact with their surroundings are very important elements of water and environmental engineering, but how do engineers calculate and visualize flows? Computational fluid dynamics (CFD) is a branch of fluid mechanics that uses numerical analysis to solve the equations of fluid motion in three dimensions (3D).

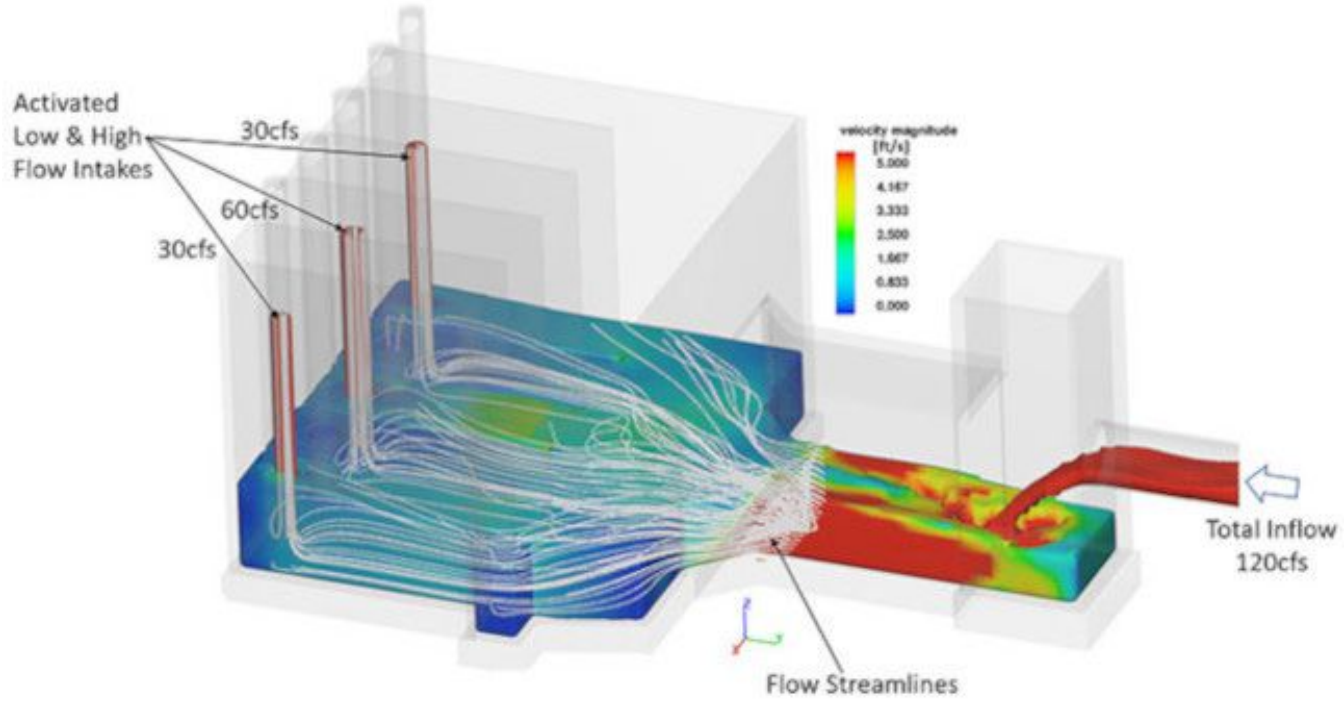
CFD analyses can also be done in two dimensions (2D); however, herein we refer to CFD in 3D, which is most commonly used in most industrial applications. The technique uses software to visualize the flow of fluids such as water and air within and around natural and artificial structures or terrains. The visualized data is used to interpret how fluid particles interact with their surroundings and can aid engineers in their project designs.

Five applications of CFD

CFD can be used in a wide variety of engineering applications ranging from building structures to water and wastewater infrastructure projects. Some of the primary applications of CFD in our firm's work include:

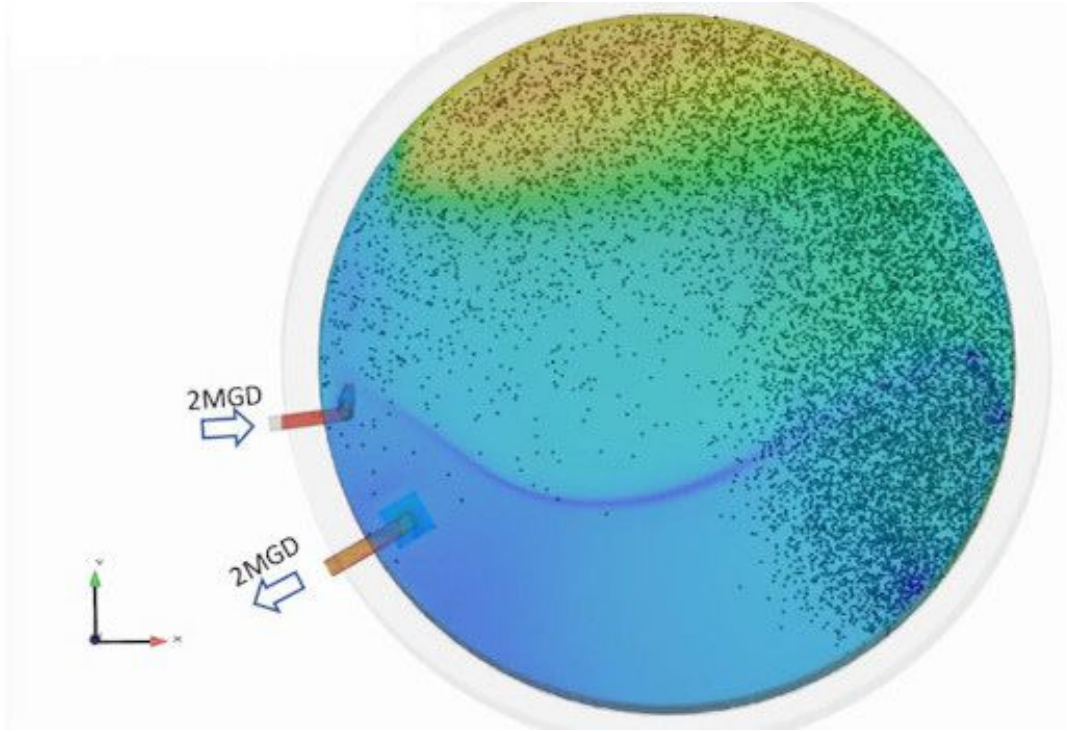
1. Designing for new or retrofitting existing water pump stations

When we are designing a new pump station that will discharge to a pipe, river, or lake,



Pump intake operational and geometric optimization using CFD.

one of the main objectives of the designer is to minimize potential head losses and uneven flow distributions in order to optimize system performance. Asymmetric flows approaching pump intakes can lead to high-flow instabilities in the vicinity of pump blades causing, in many occasions, significant vibrations that might lead to either total blade collapse or pumping efficiency reduction, at the very least. With the help of CFD, we can devise geometric configurations to modify how the flow approaches the pumps, optimize it, and enhance its uniformity to reduce turbulence on its way to the pump blades. To accomplish this, we can look at modifying the transition between the inlet conduits and the wet well, as well as the addition of guide walls and bottom seals to minimize recirculation zones and flow unevenness into and within the wet well.



Simulated flow velocity contour and particle propagation in a clearwell under equal inflow and outflow of 2MGD after 1,000 seconds.

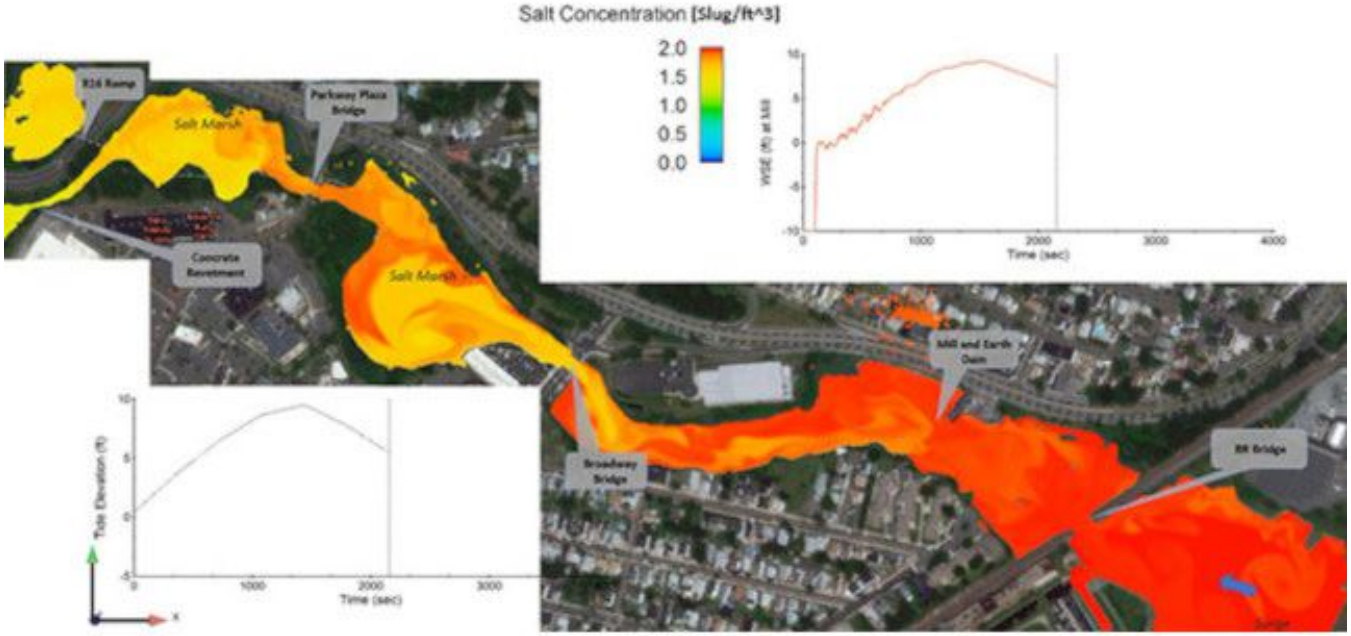
A prime example of this is a CFD study we performed for a client in the central valley region of California, where we used CFD to aid the design of a new pump station intake. Headlosses and flow unevenness were minimized via geometric modifications of the inlet channel and guide walls within the wet well. Pump operational levels were optimized to reduce the potential formation of undesired free surface and subsurface vortices that could threaten the optimum performance of the pump station.

2. Estimating head losses and the capacity of hydraulic structures in streams

We also evaluate the conveyance capacity of hydraulic structures such as bridges

and box culverts. For instance, in the case of bridges, CFD can provide an accurate description of the head losses through the structure and, ultimately, the hydraulic capacity of the bridge, i.e., the maximum discharge that can be transferred from upstream to downstream without overtopping the bridge deck.

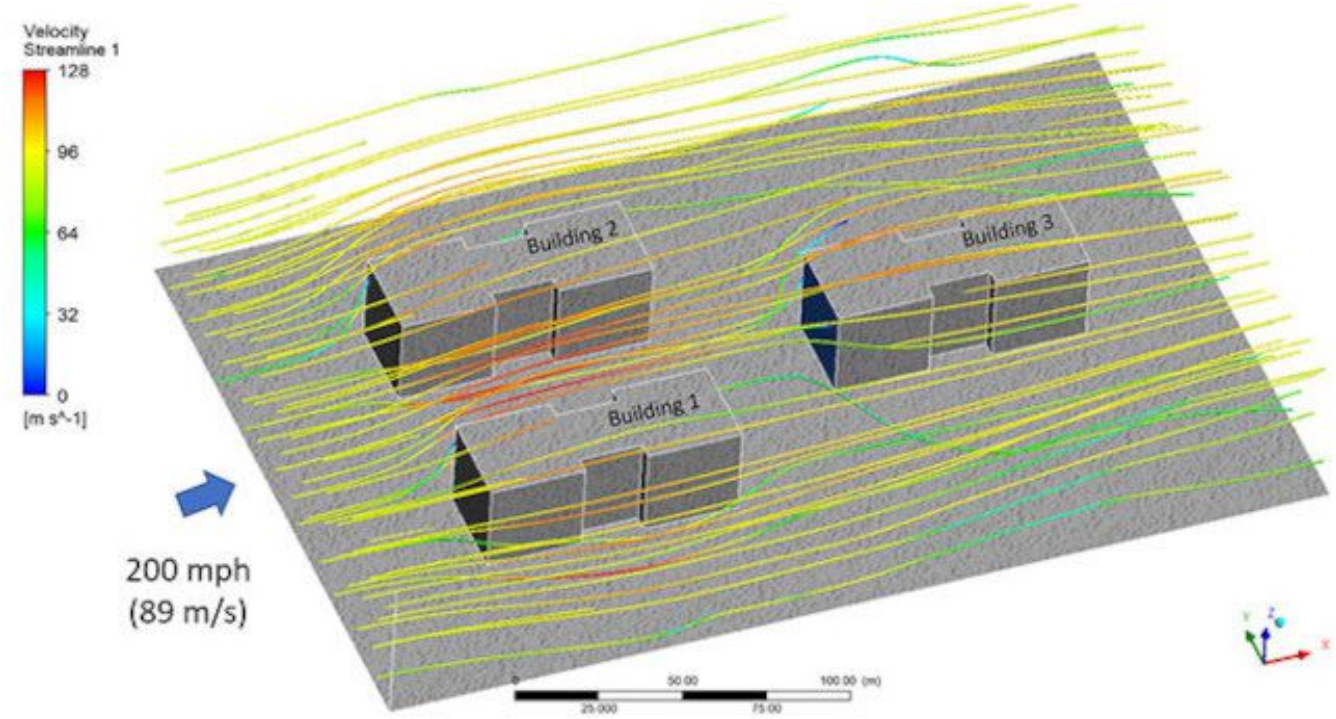
If there is a heavy rainfall event upstream of that bridge, we can use CFD to estimate the maximum amount of water that can pass through it. The design team is often tasked to confirm that the bridge can pass a flow discharge for a specific design storm event, like a rainfall with a 25-year return period. If the event is bigger than the one that the bridge is able to accommodate, we use CFD to determine alternative designs to retrofit or modify the bridge.



Simulated saltwater intrusion in a tidal creek during storm surge conditions.

3. Optimizing flow distribution in wastewater treatment plants and the effectiveness of treatment units

CFD can be used to help designers optimize different water treatment units, such as aeration tanks, grit chambers, equalization basins, primary and secondary clarifiers, and filtration units. For example, CFD is used to optimize the sediment trapping efficiency of grit chambers by designing geometric configurations that promote grit settling by enhancing flow circulation patterns within the unit by modifying the inlet and outlet conduits. By optimizing flow velocity patterns, solids will deposit at the bottom of the grit chamber more effectively. This process helps to enhance sediment trapping efficiency in a very cost-effective manner, by reducing, and not eliminating, the need for physical modeling testing iterations.



Simulation of wind forces on buildings.

4. Calculating the deposit of pollutants in a given body of water

When we evaluate stormwater runoff, such as in a stream, there could be runoff coming from both rural and urban tributary areas. This runoff is usually accompanied by pollutants, such as nitrogen, phosphorus, and even oils that enter the stream. For example, native fauna and flora in marshes along tidal creeks may be greatly endangered by such pollutants, especially when these are not evacuated efficiently. The CFD allows us to estimate how long it will take for those pollutants to deposit to the bottom of the stream or if they will be carried out by the flow downstream. This depends on how high or low the flow velocities are as a function of sedimentation processes along the stream. CFD modeling can assist the design of measures to promote the effective flushing of pollutant away from marsh areas and ul-

timately optimize the efficacy of proposed stream restoration efforts under present and future precipitation and sea level conditions.

5. Estimating wind forces on buildings

CFD has become an effective tool that helps architects and civil engineers in the understanding of flow patterns around buildings and forces on landscape assets. In this manner, CFD simulations are used to aid in the optimization of architectural assets by seeking to minimize damaging effects under extreme winds and comply with design codes and standards. CFD is also used to evaluate pedestrian comfort in urban areas and to estimate drag coefficients and forces on bridges.

What's next for CFD?

One of the exciting next steps in the evolution of using CFD tools is to enhance its reliability in sediment transport studies evaluations and pollutant tracking. The challenge with using CFD for these applications is that it isn't as simple as a "plug and play," since it requires extensive model calibration and validation. The interaction of fluids with other elements like pollutants, solids, or other particles carries out considerable levels of uncertainty in the data and modeling. To respond to this uncertainty, in many cases we've used physical testing to calibrate and validate our numerical models. While we have made great strides in research for developing models for cohesive and non-cohesive sediment transport and particle dynamics, the need remains to go to the laboratory, build a scaled model, and validate the numerical model. Fortunately, with each study, numerical schemes are improving over time as more data becomes available, and more literature is produced with studies and findings that can be used to support CFD development.

Yovanni Cataño

Building envelope assessments: From pre-design to construction

There are many aspects to a building envelope assessment and it's crucial the consulting engineer takes them all into account.

When selecting components for the building envelope, several critical characteristics need to be considered, particularly for exterior walls: resistance to air leakage, water, structural performance, durability, security, seismic performance, movement and condensation are all examples.

It is important to ensure the facade and fenestration systems used to create them can withstand any number of concerns. From the natural (hurricanes/storms, earthquakes, extreme temperature) to the human-made (fires, bomb blast, noise), there are many of events and components exterior walls must be able to withstand. Assessing these fenestration systems in advance of construction can help ensure the right products are being used for the project at hand.

When assessing building enclosure materials, it is important to keep in mind the goal of the building envelope. Is it to be aesthetically pleasing? Meet U.S. Green Building Council LEED requirements? Is it purely functional? Is the project aiming for energy efficiency or other reliability concerns? When will the façade and fenestration systems be assessed for these characteristics? Assessments can be done in the pre-design, design, preconstruction or construction phase. Each has its own uses, but each is handled differently, so it is important to consider the phase along with testing needs.

Design considerations for building envelope

Pre-design considerations are made to ensure the enclosure reflects occupant use, climatic conditions, heating and cooling and life cycle expectations. It is important to understand what is wanted/needed and budget accordingly, establish the project performance requirements, compare design concepts to those requirements and use performance goals to make design decisions. During the design phase, critical decisions include selection of systems/components; review of construction sequencing and scheduling; assessing component/system integration and transitions, as well as system compatibility; considerations around workmanship dependency on performance; thermal modeling; hygrothermal modeling; and integrating performance requirements into design documents.

Once the project is in place and underway and materials have been selected and obtained, it can be critical to assess materials to ensure they really will perform as needed against natural and human-made events, sustaining durability, security, performance and other concerns. Evaluations can be run early in the construction phase or even once construction is underway. Early on, before construction starting, mock-up testing can provide valuable information.

A pre-construction mock-up is a full-size representation of the proposed exterior wall system built to study proposed construction details, test for performance and possibly judge appearance of the exterior wall system. A lab pre-construction mock-up is constructed and assessed to assess things like structure, air tightness, water infiltration (if any), condensation behavior, construction detail identification, construction method review, ability to address future problems/changes if needed, code compliance and job specification compliance.

When deciding what type of mock-up to test and what to include in it, include typical details for the job like an accurate representation of the wall design, specialty details and all anchorage types and conditions. Anchorage types and conditions will play a big factor in test chamber set up. These include support/end conditions, longest spans, corners and inside/ outside/other angles. System transitions, like curtain wall to panel or panel to brick, must also be factored in, as well as the building size and conditions. Architects, consultants, building owners and manufacturers can all play an important role in these decisions.

The pre-construction mock-up test chamber is representative of the project specific anchorage. The design, construction and placement of the test chamber is a very important process. All chambers are different. Test labs should use job drawings to design a representative test structure, attached to test walls that recreates the real job conditions. Always ask the lab to provide a set of chamber drawings for approval before construction begins.

Building envelope testing and certification

Once constructed, the mock-up will undergo a series of testing, including static air infiltration, static and dynamic water penetration, structural performance/wind loads, seismic and in some cases thermal cycling and condensation resistance. Data is compiled into a final report and this information can then be used to proceed with a project, make additional changes/adjustments or reassess the project needs and how they can be met.

Once construction has started, field testing can be performed to certify or validate product performance ratings. In such cases, installed products can be evaluated to verify performance and installation. Forensic testing may also be done on assemblies or structures with known water problems.

Common field tests include Fenestration and Glazing Industry Alliance AAMA 502 and AAM 503, which use air infiltration/exfiltration, per ASTM E783 and water penetration tests, ASTM E1105. Specialty tests can also be helpful to assess acoustics; thermal concerns; glass for bowing, warping and frost points; masonry anchors for shear and tension; structural performance; roof characteristics; and more. Specialty tests can be done for any number of reasons at different points in the project, such as early in the installation, different intervals of installation (5%, 50% and 90% done are typical); throughout the entire installation, before the installation of interior finishes, such as insulation, drywall, trims, etc.; and before project completion. The number of tests and when they are performed depends on the specific project.

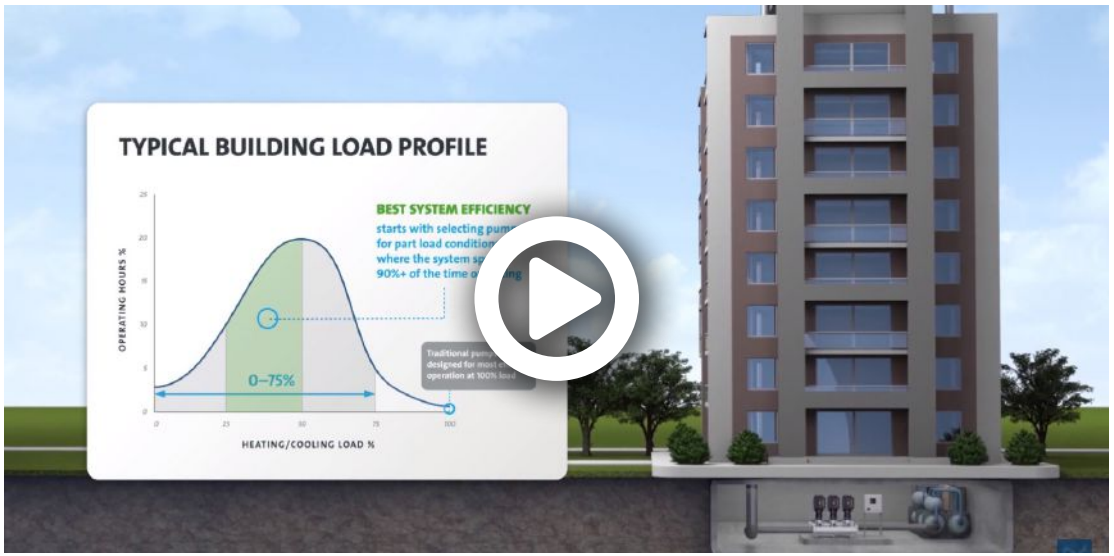
There are many internal and exterior forces that act against the building enclosure, which is comprised of many components and systems. A high-performing building is achieved by understanding the acting forces, as well as the building enclosure components and by implementing a quality assurance program and conducting testing to verify performance. All of this leads to a critical understanding of the performance characteristics of a building's exterior wall per the job specifications.

Test the unique façade conditions used on a job. Review project specifications before a job starts and test to mitigate risk before, during and after construction. This will help ensure project success and satisfaction.

Jose Colon

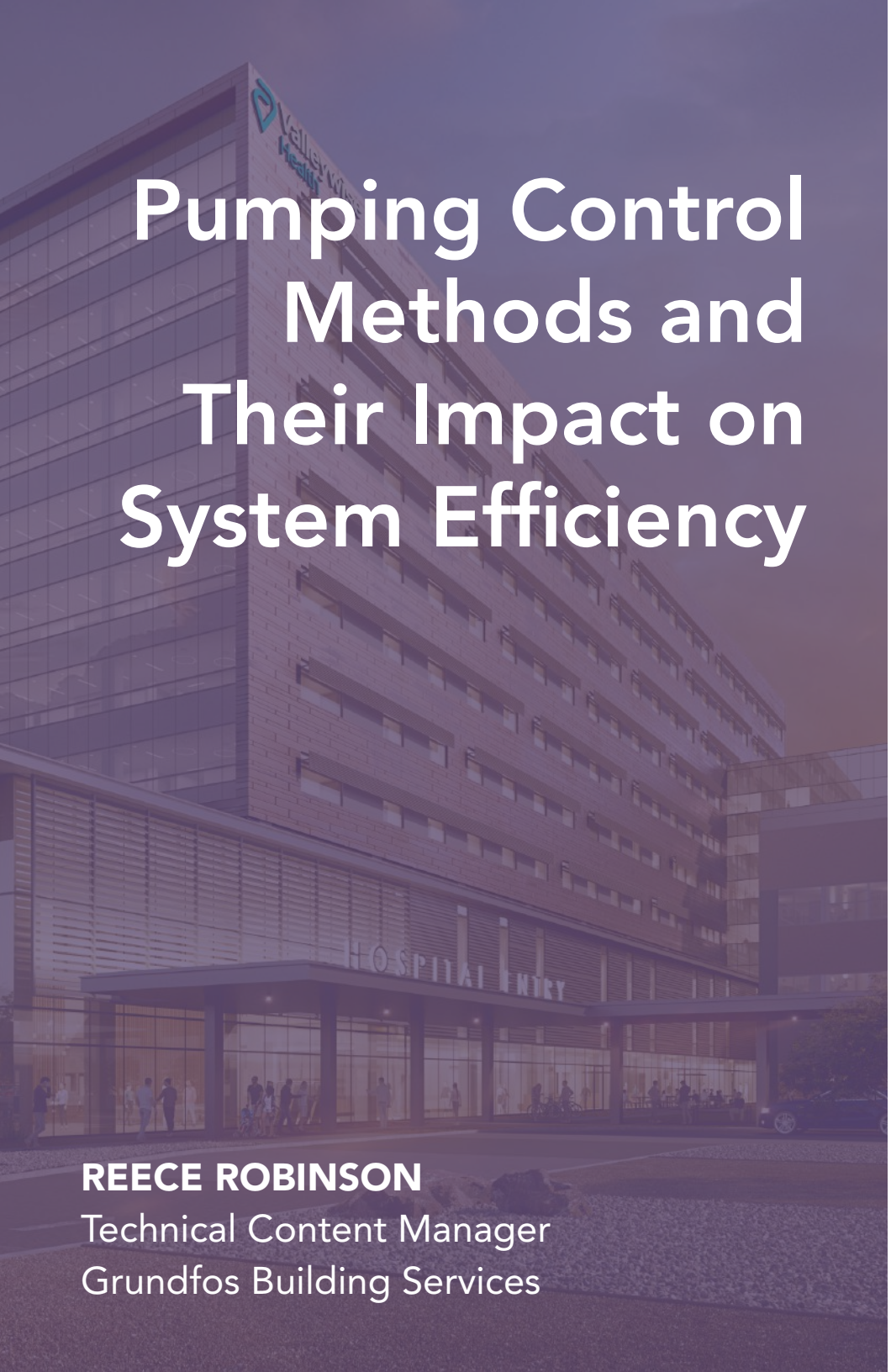
Jose Colon *is regional sales director at Intertek, a CFE Media content partner.*

GRUNDFOS



Modular Pumping Systems for HVAC: Delivering and Maintaining Building Efficiency

Today's engineers face increased pressure to deliver greater building efficiency, with tighter timelines and smaller budgets.



Pumping Control Methods and Their Impact on System Efficiency

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Technical Content Manager
Grundfos Building Services

When it comes to designing commercial HVAC and plumbing systems, engineers have to overcome a number of challenges. While everyone faces perennial budget and timeline issues, system efficiency is becoming a bigger concern every year. In this white paper, we'll discuss the role of pumps in hydronic and pressure boosting applications, as we focus on the various pumping control methods and the significant impact they have on overall system performance and efficiency.

Today's Focus on Efficiency

In recent years, commercial building energy codes have gotten tighter in response to environmental concerns and consumer preferences. The result of national efforts like the ASHRAE code requirements, LEED certification, Energy Star and the Department of Energy's Energy Efficiency Programs is that over a span of nearly 40 years, buildings have become 50% more efficient.[1] At the same time, designing systems to meet the new regulations has become more of a challenge. In states like California, where Title 24 calls for even more stringent efficiency requirements, this focus is amplified.

This means both engineers and contractors have to understand all the tools at their disposal for increasing system efficiency.

Complex systems may have multiple remote sensors and control logic to adjust pump system set-point accordingly.

The Importance of Pumps

Pumps are the heart of any commercial HVAC or pressure boosting system, so they are the key to how the system performs. Pump manufacturers strive to create pumps that offer the highest possible efficiencies, with mechanical enhancements and permanent magnet motors that deliver energy-saving variable speed pump performance.

In 2015, the Department of Energy (DOE) upped the ante and mandated new pump efficiency standards that will take effect in 2020. As a result of the new measure, the DOE projects that over the course of 30 years, pumps meeting these standards will reduce electricity consumption by about 30 billion kilowatt-hours — the equivalent of the annual electricity use of 2.8 million US households.[2]

As the intended outcome of the DOE mandate demonstrates, pump efficiency goes way beyond the pump itself and extends to the vital role pumps play in the overall energy consumption of the buildings in which they operate. In other words, in both HVAC and plumbing applications, the key to success is overall system efficiency. And that's where pump control methods play an important role.

Variable Pressure Is Key to Efficiency

In a nutshell, variable pressure control is a method used in variable speed pumping that results in reduced pump energy costs. Variable pressure encompasses a number of control modes where pump head is reduced either linearly or quadratically as flow is reduced.

While the terms "proportional pressure control" and even "quadratic proportional pressure control" are frequently used, combining these words results in an oxymoron. Mathematically, the term "proportional" describes a linear relationship, while "quadratic" describes a non-linear relationship. For this reason, quadratic pressure control should not be a subset of proportional control.

Applications

In HVAC systems, variable pressure control is most common in closed system (hydronic) applications configured as variable / primary or secondary pumping systems, where water is pumped to heating / cooling coils or air handling units (AHUs) with modulating control valves.

In pressure boosting systems, this type of control is used in municipal water supply and service water boosting in commercial buildings.

An illustration of why variable pressure control is preferred in these applications can be seen in Figure 1, which shows what happens when an uncontrolled (fixed speed) centrifugal pump is used instead.

Notice that the pump head rises as flow is reduced. This is quite often the exact opposite of what is needed to provide the required flow. Variable pressure control eliminates this problem, delivering lower pressure as flow reduces. This ultimately results in greater efficiency and lower energy costs.

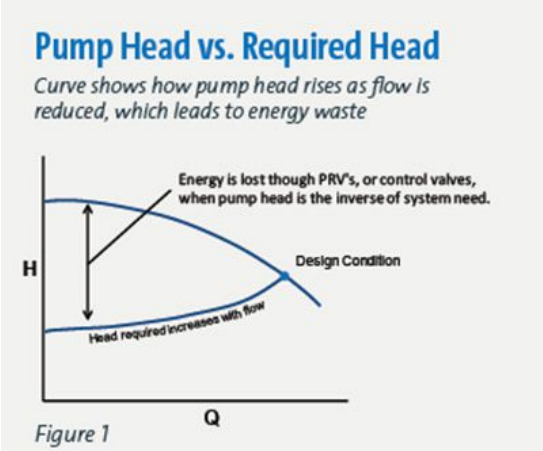


Figure 1

Changing Flow Demand

Variable pressure adapts to changes in flow demand, delivering efficient performance even during partial-load scenarios, which occur much more often than full-load situations. For example, a chilled water circulation system can have low flow demands in the spring and fall months, and a service water booster system can have low flow demands during off-peak hours. The pump head required during these lowflow periods can be significantly lower than what is required at peak (design) flow periods due to the reduced friction losses in the pipes and fittings. Because of the hydraulic relationship between pressure and flow in piping systems, pump operation can be controlled by only measuring pressure, without the need to measure flow.

Measuring Pressure

There are several options for measuring pressure, including type of equipment, and where it's located. Because they are less intrusive and inexpensive, pressure sensors have become more popular than flow sensors. Pump systems with pressure sensors (differential pressure or individual suction and discharge pressure sensors) will calculate flow based on the differential pressure across the pump, or a combination of differential pressure and power. Pump performance data is loaded into the pump control. Power-based pump control, or controls operating without sensors, have gained popularity over the last 10 years as well. Here, pump performance curves are loaded into the pump control and both pressure and flow are estimated using the power consumed by the

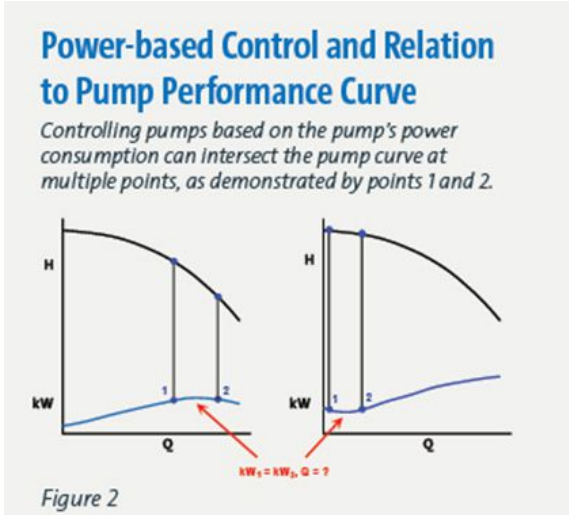


Figure 2

motor and drive. Caution must be taken when using power-based control, as this method does not work on all pump types. Since the only thing being measured is motor input power (via the variable frequency drive), there may be two points on the pump curve that require the same power. An example is shown below in Figure 2.

Regardless, the use of both pressure sensors and power-based control results in some form of variable pressure control.

Common misconception: "If a pump-mounted sensor is used, the pump can only operate in constant pressure mode." This is incorrect, as current pump technology allows proportional and / or quadratic pressure control even in systems with pump mounted sensors.

There are four main types of pressure control for centrifugal pumps: constant pressure, proportional pressure, quadratic pressure, and constant pressure using a remote sensor. Figure 3 below shows the control curves for each of these pressure control types in blue.

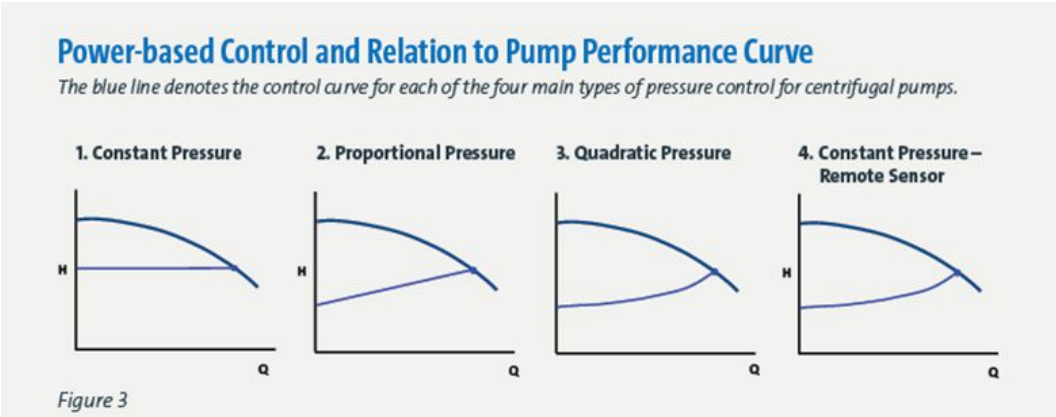


Figure 3

1. Constant pressure mode

Constant pressure is technically not considered variable pressure control, but is a standard control mode for variable speed pumps. It is very widely used in service water boosting and is occasionally required for hydronic circulation systems, especially in those with higher-than normal pressures in low-flow conditions.

2. Proportional pressure mode

In this mode, the pump head is reduced linearly with flow.

3. Quadratic pressure mode

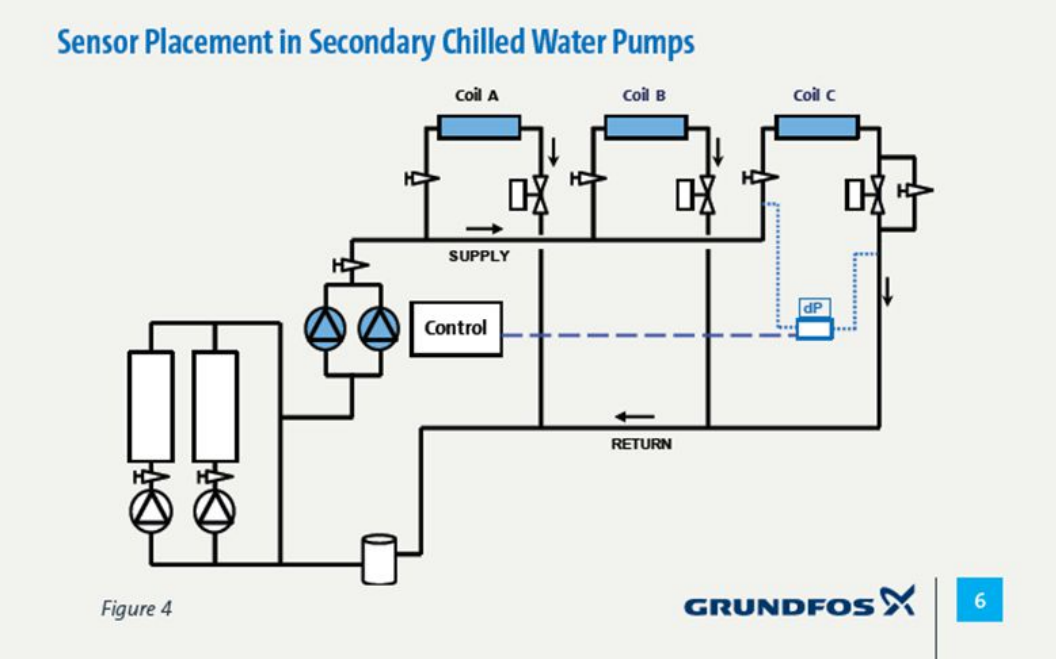
Quadratic (or squared) pressure best simulates the characteristics of a system resistance curve, because friction losses have a quadratic relationship with flow.

4. Constant pressure remote mode

This control mode uses a system-mounted sensor that is strategically placed in the piping system. Notice on the graphs in Figure 3 that the resulting control curve can essentially be the same for both quadratic control and constant pressure remote.

The first three control modes — constant pressure, proportional pressure and quadratic pressure — can be what are called "preprogrammed" control modes and can be used with pump- or system–mounted sensors and / or power-based pump control.

Some basic examples of pump and piping configurations with sensor placement are shown in Figures 4 and 5. Obviously, options for placement will vary significantly based on project requirements.



Pump-mounted vs. Remote Sensor

As previously mentioned, there are two ways to use sensors: either mounted on the pump or attached remotely. Following is a brief overview of how each configuration is used in both hydronic and pressure boosting applications.

Pump-mounted Sensor

When pump-mounted sensors or powerbased control are used (Figure 6), there must be two setpoints: head / pressure at design (or maximum) flow (A), and head / pressure at zero flow (B). These two settings define the control curve characteristics. To properly set these parameters during commissioning, the head at zero flow (i.e., fixed head) needs to be determined. This fixed head is also referred to as control head

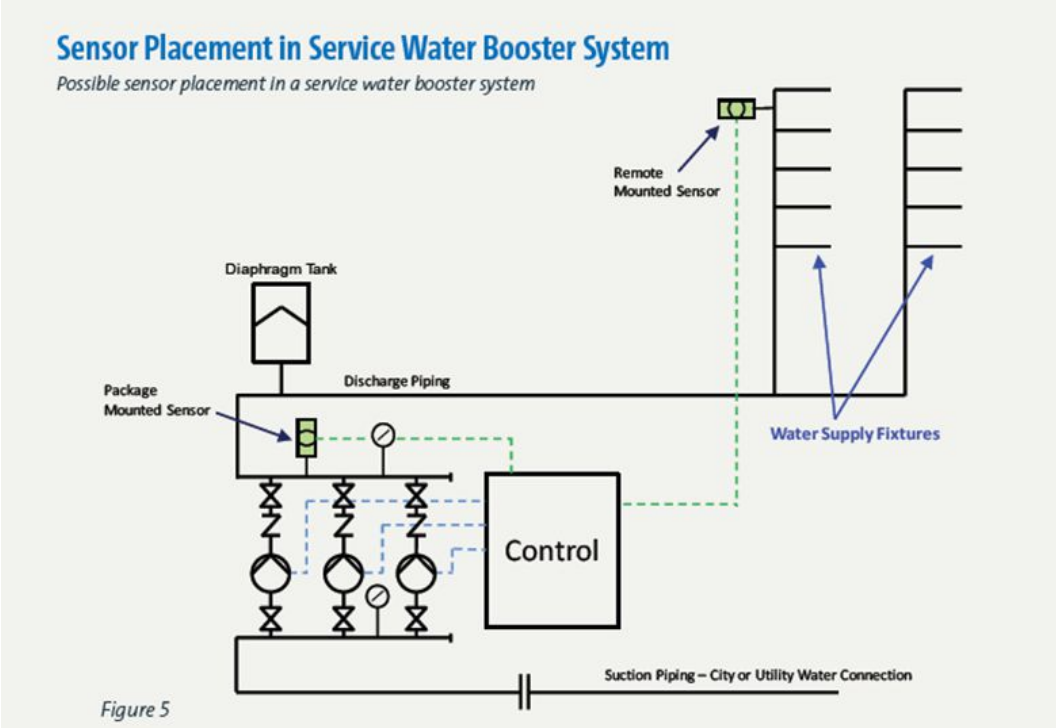


Figure 5

Hydronic application:

For a hydronic circulation system, similar to the example illustrated in Figure 4, the fixed head would also represent the control head required if a remote mounted differential pressure sensor were used.

Example:

Mode: Quadratic pressure control
Total head: 60 feet (26 psi)
Fixed head: 30 feet (13 psi)

Therefore, the head at zero flow would be programmed to 13 psi, and the total head

would be programmed to 26 psi to represent the 50% reduction in head from design flow to zero flow.

Pressure boosting application:

Like the example illustrated in Figure 5, the head at zero flow will be the elevation head (i.e., static head), plus the residual pressure required at the fixture furthest from the pump system. An example of this might be a 10-story building with a setpoint pressure of 85 psi at maximum flow with an inlet pressure of 30 psi. This equates to a boost pressure of 55 psi or a total head of 127 feet.

Example:

Mode: Quadratic pressure control
Total head: 127 (55 psi)
Fixed head: 115 (50 psi)

Therefore, the head at zero flow might be 80 psi with 50 psi being the static head and 30 psi representing the residual pressure. The remaining five psi would be the only variable component of the pump head coming in the way of friction.

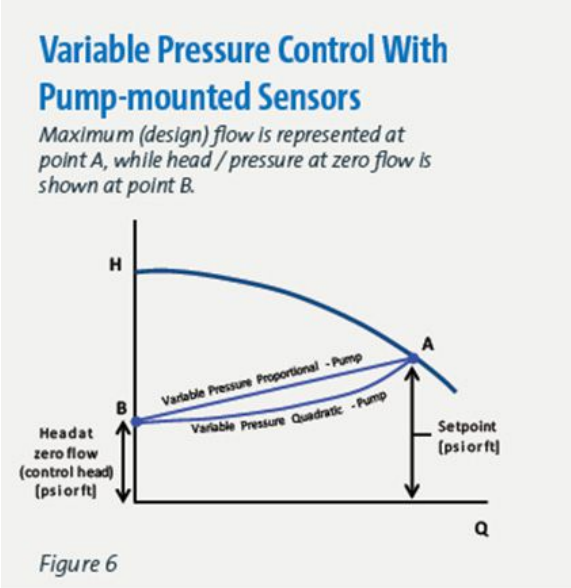


Figure 6

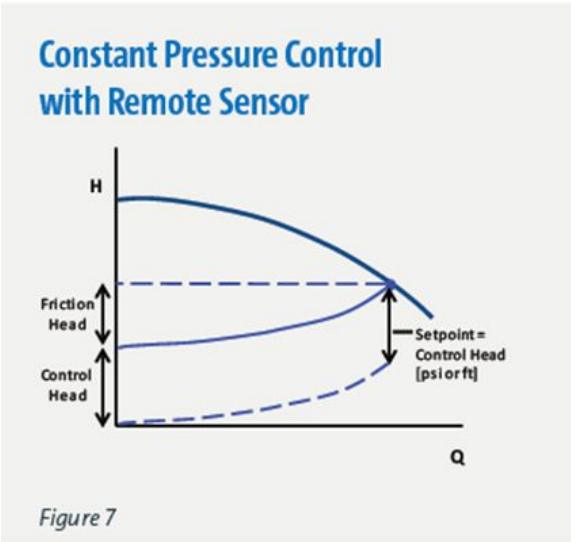


Figure 7

The frictional component of pump head in booster systems for multi-story buildings is typically less than 10% of the total head. The percentage of head reduction in hydronic circulation systems will be much greater than those in pressure boosting systems.

Remote Sensor

The last of the four pressure-based control modes involves the use of a remote sensor (Figure 7). When using remote sensors, only a remote system set-point is required for the pump system controller.

Hydronic application:

In a hydronic circulation system, a differential pressure sensor is typically installed at a strategic location in the piping. The secondary chilled water system example in Figure 4 shows a differential pressure (dP) sensor that measures the pressure loss through the coil, control valve and balancing valve. The design philosophy is that if the total pressure drop of these components is maintained at a fixed value, sufficient flow will be provided to all the other coils in the system. This sensor location is typically selected based on a worst-case pressure loss, involving long runs of the main distribution piping along with the pressure drops through the coil and valves. This sensor location is often at the end of a circulation loop but can also be 2/3 to 3/4 of the distance from the pumps to the furthest coil.

Pressure boosting application:

Instead of maintaining a constant pressure at the pump system discharge piping, a sensor is mounted at a location close to what is called the "critical fixture." The critical fixture might be located on the top floor of a multi-story building or at the furthest home from the pump system for municipal water supply.

Which is better: pump-mounted or remote-mounted sensors?

The answer depends on your specific application. However, there is one distinct advantage of remote sensors. If the frictional (variable) component of the total pump head is less than what was calculated, pumps with remote-mounted sensors can potentially operate more efficiently than systems with pump-mounted sensors. Let's go back to one of our previous examples of a hydronic circulation system to show why.

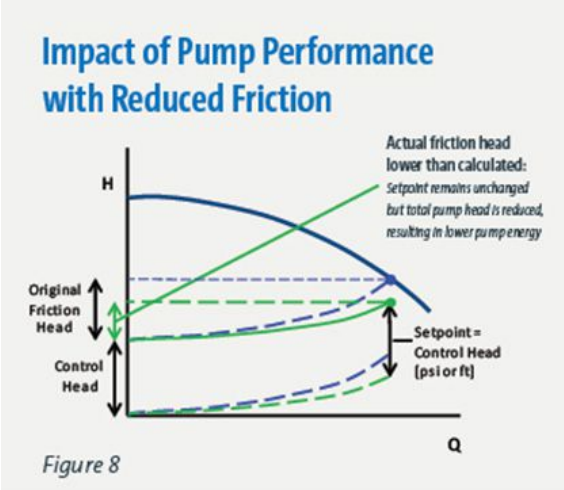


Figure 8

Example:

Mode: Quadratic pressure control
Total head: 60 feet (26 psi)
Fixed head: 30 feet (13 psi)

Therefore, the head at zero flow would be programmed to 13 psi, and the total head would be programmed to 26 psi to represent the 50% reduction in head from design flow to zero flow.

That would establish a predefined control curve resulting in pump head approaching 60 feet at peak flow rates. But what if the actual total friction loss in the system "as built" turned out to be only 10 psi instead of the calculated 13 psi? Because the only fixed head is the remote sensor setpoint of 13 psi, the total pump head as flow approaches design conditions only goes to 23 psi (10 psi + 13 psi) or 53 feet of head. In

this way, energy is saved because in the reality of actual operating conditions, 60 feet of head is not necessary. The result of this new lower total head is shown in Figure 8. Note that the remote setpoint (control head) remains unchanged yet the total pump head is reduced resulting in lower pump speed and energy.

Because total pump head is often overestimated, the use of remote sensors acts as a failsafe, effectively right-sizing the system to ensure efficient pump operation despite the differing pressures. Systems with pump-mounted sensor controls can be adjusted to reflect the lower frictional losses, and achieve this same result. However, these systems require additional monitoring and setpoint adjustments to determine the optimum setpoint.

Impact of ASHRAE Energy Standard 90.1

There is a direct connection between the ASHRAE Energy Standard 90.1[3] and the control modes discussed here. The two sections that mention pumps are:

6.5.4.2 – Hydronic Variable Flow Systems
10.4.2 – Service Water Pressure-Booster Systems

The requirement for Hydronic Variable Flow Systems states that the system must have controls that will result in pump motor demand to be no greater than 30% of design wattage at 50% of the design water flow. A proportional or quadratic pressure control mode is required to meet this requirement.

For pressure boosters, there is no energy reduction requirement, but the use of pressure regulator valves to control system discharge pressure is not allowed. This re-

quires variable speed pump controls, and a remote-mounted sensor — or software that simulates remote sensing — must be used in conjunction with variable speed controls. In both cases, quadratic pressure control or remote sensing is the preferred method to meet the requirements of the code.

Difference in Energy Consumption

Since energy savings are the primary driving factor for the use of variable pressure control, let's look at an example of the power reduction of a typical hydronic circulation pump using the different control modes. Let's examine the performance curve for a pump selected for a design-day capacity of 500 gpm at 60 feet of head (Figure 9) and the impact different control modes have on efficiency and power (Figure 10). Notice pump efficiency at low flow is greatest when quadratic control is used (peak efficiency shifts to the left).

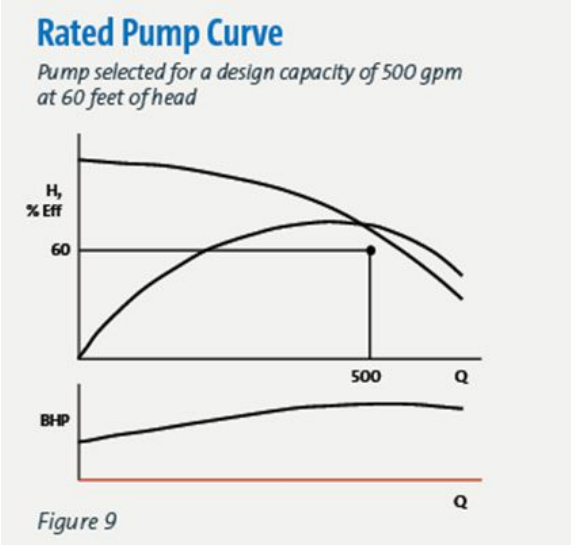


Figure 9

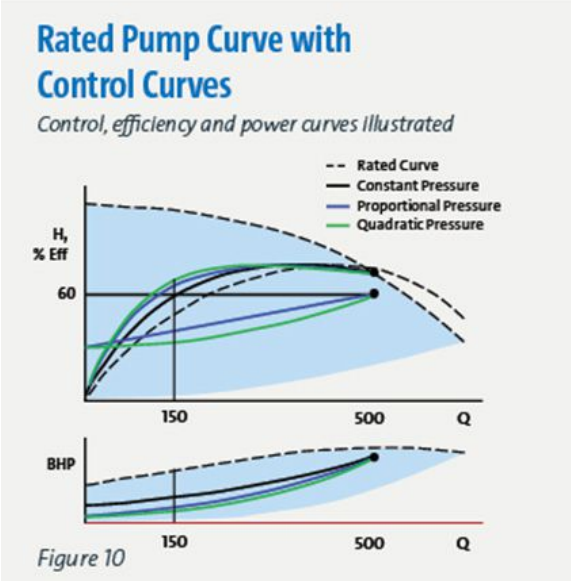


Figure 10

The most significant reduction in pump power, as seen in Table 1 is accomplished by using a constant pressure control over a fixed speed (unregulated) pump, for a 53.3% decrease in power. When moving from constant pressure to proportional pressure,

another big drop in power is achieved, reducing power by another 42%. Lastly, when moving from proportional pressure control to quadratic control, an additional power reduction of 19.5% can be achieved. When looking at just the three variable speed-controlled pumps, the largest reduction in power occurs when moving from constant pressure to proportional pressure. It may not always be possible to utilize quadratic control or even proportional pressure control, so it's important to understand that there still can be significant energy savings when using constant pressure control over fixed speed pumps. This is most important when looking at replacing existing fixed speed pumps.

Parallel Pump Control

The use of parallel pumping can help to achieve even greater efficiencies, as smaller pumps can be used, and duty can be distributed in a much more efficient manner. When using parallel connected pumps, especially with pump-mounted or powerbased sensing, make sure that the control curve is set to incorporate all connected duty pumps as shown in Figure 11 . Individual pumps often come with integrated controls that can be field-connected to work in parallel. This can result in pumps operating on single pump control curves that can produce more head than necessary and can consume more energy than is required.

Performance Comparison at 150 gpm

Impact of control mode on pump with a performance at 150 gpm, or 30% of design flow.

Control Mode	Speed [rpm]	H [ft]	Eff [%]	bhp	Savings
Unregulated	3500	108.3	48.1	8.53	–
Constant Pressure	2657	60	57.2	3.98	53.30%
Proportional Pressure	2165	39	63.9	2.31	42.00%
Quadratic Pressure	1994	32.7	66.5	1.86	19.50%

Table 1

The use of packaged systems built to incorporate parallel pumps helps reduce the extra work of configuring individual pumps with individual controls into a multi-pump parallel system.

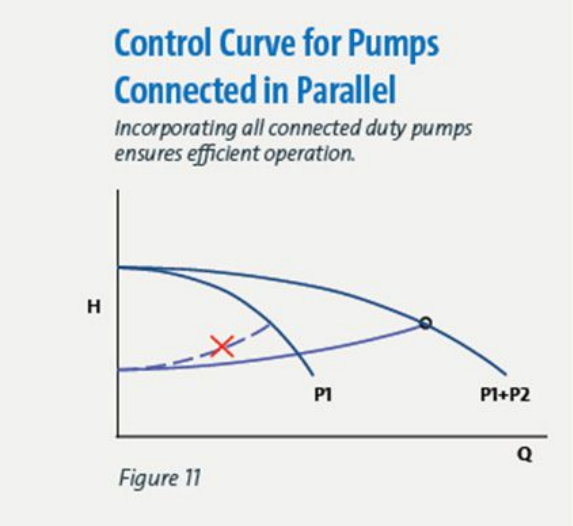


Figure 11

Conclusion

By now you've gathered that for most systems, the quadratic control curve will result in the greatest energy savings, provided the controls are programmed to match the system characteristics. But it's not always easy to achieve the desired results with field-built pump systems where pumps, drives and controls come from different manufacturers. Connecting two or more pumps in parallel, which is often required, adds another level of difficulty, as the controls need to be set up for redundancy and / or cascade operation.

One way to eliminate many of these challenges is by choosing a packaged pumping system. Packaged systems can come with sensors on the inlet and outlet manifolds (or differential pressure sensors), and can be programmed to provide either proportional or quadratic pressure control. Any set-point changes can be made on a single pump controller either at the control panel or through the building management system (BMS).

When remote sensors are used, many packaged systems can be programmed to provide pressure control in the event of a remote sensor failure.

When the remote sensor signal is lost, the packaged system can revert to the package mounted sensors while the remote sensor problem is being resolved. In some cases, the remote sensor location can turn out to be suboptimal. While a new remote sensor location is being tested, package-mounted sensors can provide the needed backup control.

Another benefit that comes with the packaged system is ease of integration to the BMS. All information regarding pumps, drives, controls and sensors can be transmitted through a single pump controller.

While energy efficiency continues to grow in importance, it seems project completion time and budgets continue to shrink proportionally. Faced with these challenges, engineers must begin to think about new ways to accomplish old tasks. The use of variable pressure control modes, a sensor system that best fits your application, and the consideration of packaged pumping systems can all be combined to achieve better results in less time, while saving money.

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Selecting the right building automation partner

Building owners and operators are facing even larger obstacles in keeping their systems running smoothly, which makes picking the right partner more important than ever.

In light of the current situation in the world today, building owners and operators are facing even larger obstacles in keeping their mechanical HVAC and building automation systems running efficiently, reliably and safely.

While energy efficiencies and savings remain a top priority, closer attention to ventilation rates, indoor air quality (IAQ) and humidity levels within the building infrastructure are proving to be equally important due to the current threat of viruses.

Moving forward, these areas will be even more scrutinized in order to protect staff and visitors. The challenge to address these areas properly is to select a contractor that takes a holistic approach to not only meet your financial and operating objectives, but can also provide solutions to keep people safe by promoting a healthy building.

To begin, select a contractor based on their organization's core values. First and foremost, ask: Is their common interest in promoting a healthy building? Are they relationship-minded, collaborative, and innovative? Do they have the resources and service offerings to be your one phone call, allowing you and your building to operate successfully?

Day to day, it is important that service providers strive to make clients' lives easier by providing an opportunity to get granular with preventative maintenance services on a budget and operational level.

Consider these questions:

- What are your owning and operating costs?
- What key performance indicators (KPIs) drive your facility budget?
- Have you benchmarked your HVAC equipment?
- Are you meeting your equipment lifecycle goals?
- Are you paying too much in utilities?
- Are you promoting a healthy building?

Having answers to these questions will put you on the path to future success. By not overlooking maintenance as a service due to costs, there can be a lot of value in utilizing a data-driven approach to maintenance.

When choosing a building solutions provider, it's important to select a partner that is uniquely positioned to assist answering the questions surrounding these issues as well as solving them.

Jeremy Crowley

Jeremy Crowley *is a senior account consultant at Envise.*

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- Black screens absorb UV rays from the sun, are flexible and non-conductive to cold temperatures; help prevent flash-freezing and unabated snow entry into system.
- Also highly-effective at filtering airborne debris during the spring, summer and fall; provide measurable savings in energy and maintenance costs.

Winter season snow build-up inside air intake chambers and plenums can damage expensive internal air filters and lead to snow melt damage to ceilings and walls! The end-result is a drain on maintenance time and budgets due to ceiling and wall repairs, unplanned filter replacements, and problems related to unfiltered air entering the building.

Snow Stopper™ Screens Mount inside or outside louvers and on rooftop air handling units for a snow barrier at point of entry.

› CLICK HERE ‹ TO LEARN MORE, OR CALL AIR SOLUTION COMPANY AT 800-819-2869

Air Solution COMPANY

Air Solution COMPANY
Cottonwood Filter Screens

Air Solution Company Cottonwood Filter Screens For HVAC and Cooling Tower Equipment

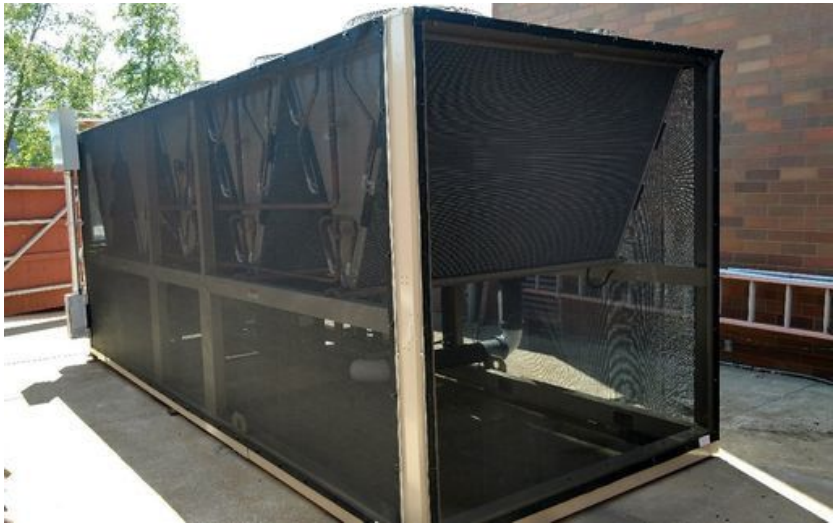
Air Intake Filter Screens For HVAC Equipment (commonly called Cottonwood Filter Screens). Stops airborne debris from entering air intake openings on rooftop units, condensers, chillers, dry coolers, air handling units, intake louvers and cooling towers.

Why Specifying Mechanical Engineers Should Build Cottonwood Filter Screens into Their Cooling System Designs

RANDY SIMMONS
President and Co-owner
Air Solution Company

When mechanical design engineers are tasked with designing cooling systems, it typically starts with understanding the cooling needs then determining what budget is available for development - That's when the work begins. Engineers set out to develop the most efficient system within the constraints of the allocated money and when approved and built, the project typically comes to an end when the system is eventually taken over by the building owner. But it doesn't always end there.

Out of the blue comes a phone call from the customer whose system was turned over 2 yrs., ago, complaining



about the system not performing properly - Commonly it's too hot or too humid inside the building or, process equipment is overheating - Suddenly, the engineering firm and associated OEM are in motion putting current projects aside and frequently allocating un-billable engineering resources to investigate the problem only to find that the system has not been properly maintained - this is called "Project Bounce-Back". All too often, coils haven't been cleaned or have been improperly cleaned or, belts haven't been changed, cooling tower strainers are plugged, or solenoid blow-down valves are getting wedged open due to debris build-up in the sump and not clearing the valve resulting in make-up water running sometimes for days as it tries to replenish water supply - and the list goes on and on - Bottom line is - lack of proper maintenance is typically the culprit. Why? you might ask, would maintenance not be performed on brand new equipment - well the list of potential reasons is as long as your arm but to the engineering company and OEM tasked with identifying the problem -

they are the losing parties because they not only take a hit to their bottom line when they are called into action but can't bill for their time - but they run the risk of delaying current projects on the drawing board.

How can engineering firms help prevent this from happening - It's simple, integrate Cottonwood Filter Screens into the overall design so airborne debris is stopped at its point of entry where it can be seen and easily cleaned using a broom, brush, shop vacuum, sidewalk blower or garden hose - even rain can help rinse them clean - In other words, you simplify the maintenance to a point where there is no excuse for not keeping the unit clean - no water or chemicals are needed nor is it necessary to remove the cottonwood filter screens for cleaning. In other words, they help protect the integrity of the mechanical designs.

With an ever-increasing emphasis on high efficiency equipment and in particular micro-channel condenser coils, more engineering firms are recommending them, and more customers are willing to pay the higher up-front investment cost on the premise that they will save significantly more money on energy over the life of the unit. Well

that all sounds good and makes logical sense - if in a laboratory environment; In real life practice however, it is rare that customers capture the energy savings promised by the high efficiency micro-channel coils - Why? The answer is simple - In North America, good PM practice is considered to be quarterly rather than "as needed" hence, when you consider that compared to standard efficiency condenser coils that may have 10 fins per inch while the micro-channel coils may have 20 fins per inch in the same footprint - the high efficiency micro-channel coil is a better filter than the standard efficiency coils because it captures more debris - which means it fouls out sooner between scheduled maintenance. The irony of this is that because it fouls out sooner, it runs longer in a fouled condition between quarterly cleaning - hence the very machine that can deliver an energy cost savings can actually become an "Energy Hog". How do you solve the problem? there are only three ways:

1. Don't specify micro-channel coils unless they are in a clean operating environment, or the client is willing to have them cleaned "as needed"

2. Clean them more frequently - most won't do that because of the fragile nature of the coils and the damaging effect of traditional cleaning methods and the increased labor cost.

3. Protect them with Cottonwood Filter Screens which relocates the debris load away from the coils stopping it where it is easy to clean without removal and without physical contact with the condenser coil.

In short, building in basic maintenance solutions in the mechanical design and specifying process will enable your designed system to run cleaner longer, while increasing customer satisfaction and reducing / eliminating "Project Bounce Back".

To learn more about how Cottonwood Filter Screens can help improve operational efficiency of cooling systems (rooftop units, dry coolers, chillers, cooling towers etc.) while reducing maintenance and energy cost, visit Air Solution Company at **www.airsolutioncompany.com** or, call 1-800-819-2869.

Case study: District heating supply from a combined heat and power plant

Development and operation of the combined heat and power district heating system in Jamestown, N.Y., provides energy efficiency, environmental and economic development benefits to customers

The city of Jamestown, N.Y., began providing electric service in 1891, and in 1923 established a municipal power system, the Jamestown Board of Public Utilities. The single-purpose Carlson Generating Station was selected by Joseph Technology Corp. in 1984 as the central energy source for the Jamestown combined heat and power system. The power plant at this time included two steam driven turbine-generator units (No. 5 and 6), both with General Electric nonreheat turbines.

Unit 6 was selected for CHP modification in 1984 considering its relative ease of retrofit to cogeneration. This turbine is a 25,000 kilowatt, 3,600 revolutions per minute, 15-stage single-flow condensing unit, designed to operate at 850 psig steam pressure, 900°F temperature and 3.5 inches of mercury condenser pressure. The turbine had one blanked-off extraction point at the 11th stage from which it was decided to extract steam for use in a new district heat exchanger.

Higher loads were served with the existing auxiliary heat exchanger that was arranged in series with the new district heat exchanger (see Figure 1). After unit conversion to CHP operation, the efficiency of the turbine increased by 20%.

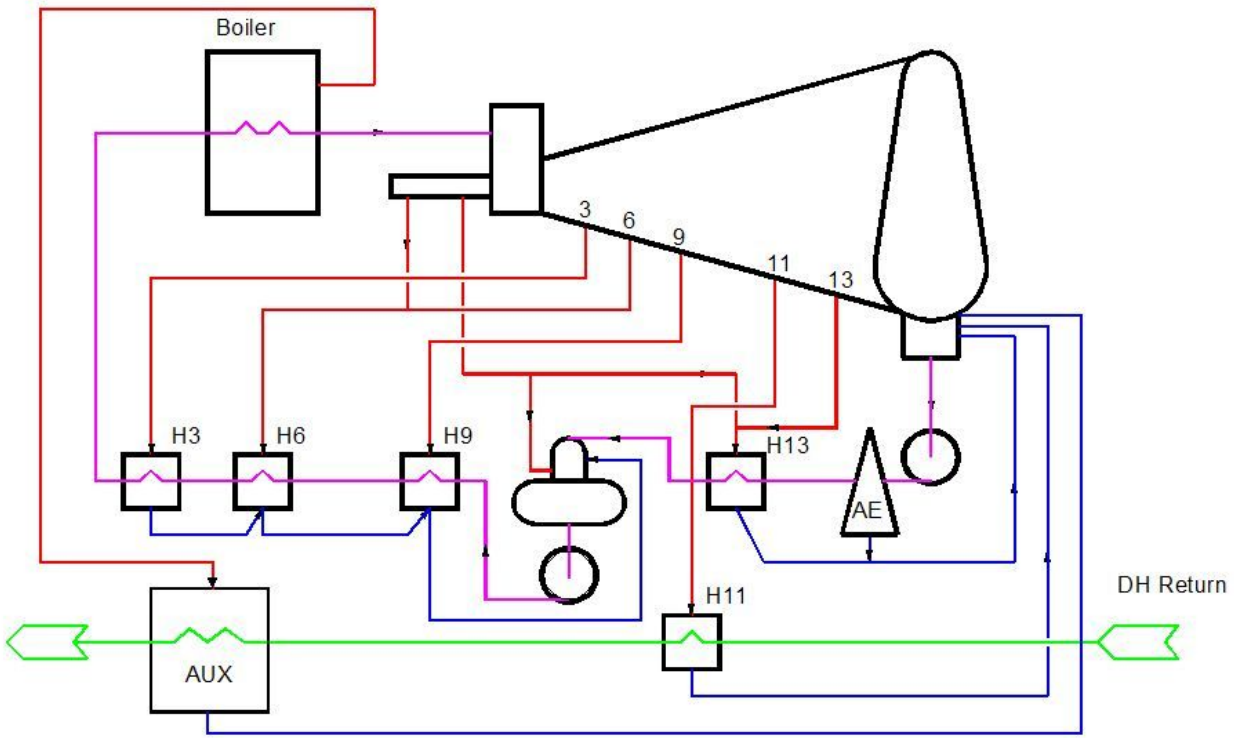
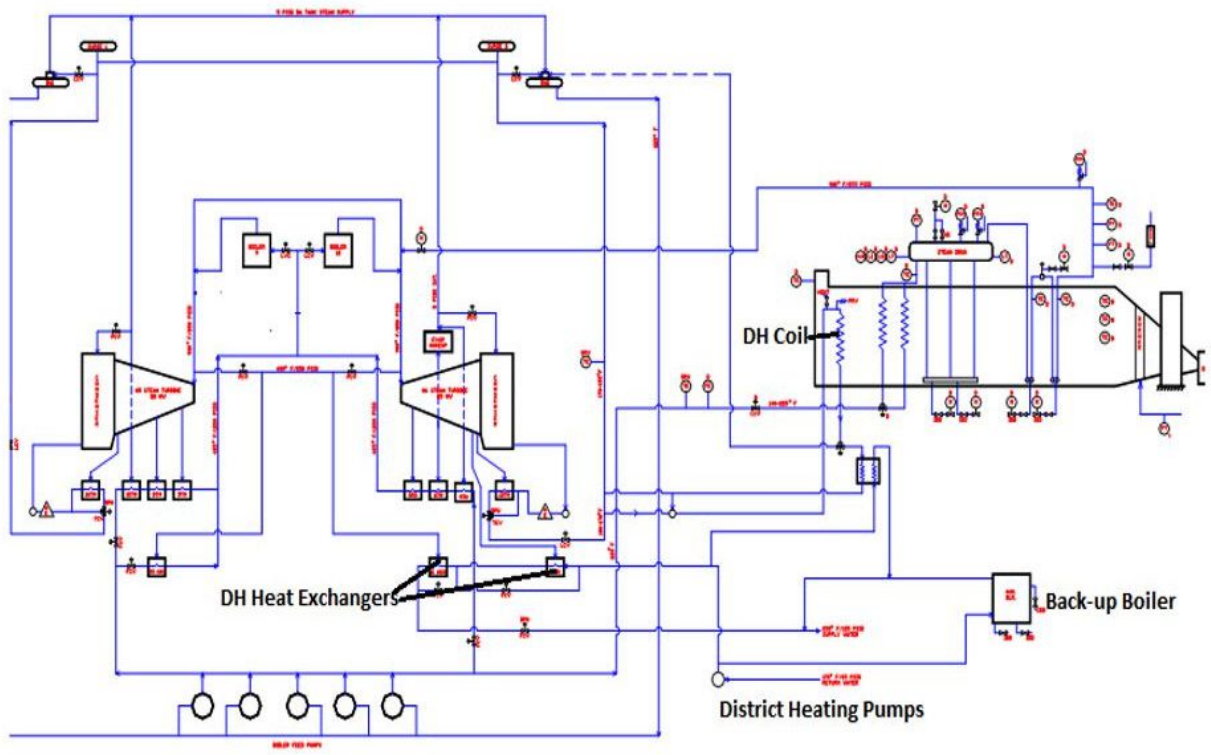


Figure 1: This shows the initial combined heat and power/district heating system. Courtesy: Joseph Technology Corp.

Later the power plant has been repowered with the General Electric LM6000 gas turbine generator designated as unit No. 7. The gas turbine was coupled with the Deltak heat recovery steam generator, which included a coil for district heating purposes (see Figure 2). The power plant also was equipped with a backup natural gas-fired hot water boiler.

Transmission and distribution network

The prefabricated piping conduit system consists of a thin-wall carbon steel carrier



pipe, polyurethane insulation, polyethylene casing and a leak detection system. The district heating piping is installed in shallow trenches requiring minimal excavation and no shoring.

Figure 2: Shown is the repowered power plant, in which the gas turbine was coupled with the heat recovery steam generator. Courtesy: Joseph Technology Corp.

The design philosophy for the building retrofits is based on the following considerations:

- A plate-type heat exchanger was used in each building to transfer heat from the district heating water supply to the building distribution system.

- The district heating water supply temperature varies according to outdoor temperature.

Existing steam and condensate piping, wherever possible, was used to form a closed hot water loop, with the installation of circulating pumps, expansion tank and air removal system. All steam traps were removed and air vents were installed at system high points.

Conversion of a gas-fired hot air heating systems involved installation of a new hot water heating coil in the return air duct, along with an associated plate-type heat exchanger and closed loop hot water circulating system.

System development

The successful development of Jamestown CHP/district heating system was the result of the strong support from the community, the city administration, the board of public utilities and New York State Energy Research and Development Authority and the technical expertise and well-orchestrated effort of the consulting engineer, Joseph Technology Corp. The overall cooperation and strong community support for the project enabled local officials to enthusiastically promote the system, to obtain financing and to meet an ambitious construction schedule.

The objective of phased implementation was to develop the system in stages, spreading the capital expenditures in incremental investments over the development period and allowing the system to generate revenues to offset the capital investment. The system was developed in three phases, starting with a pilot system in the first phase, a core system in the second phase and continuous annual growth in the third phase. The

system currently services 75 customers (see Figure 3).

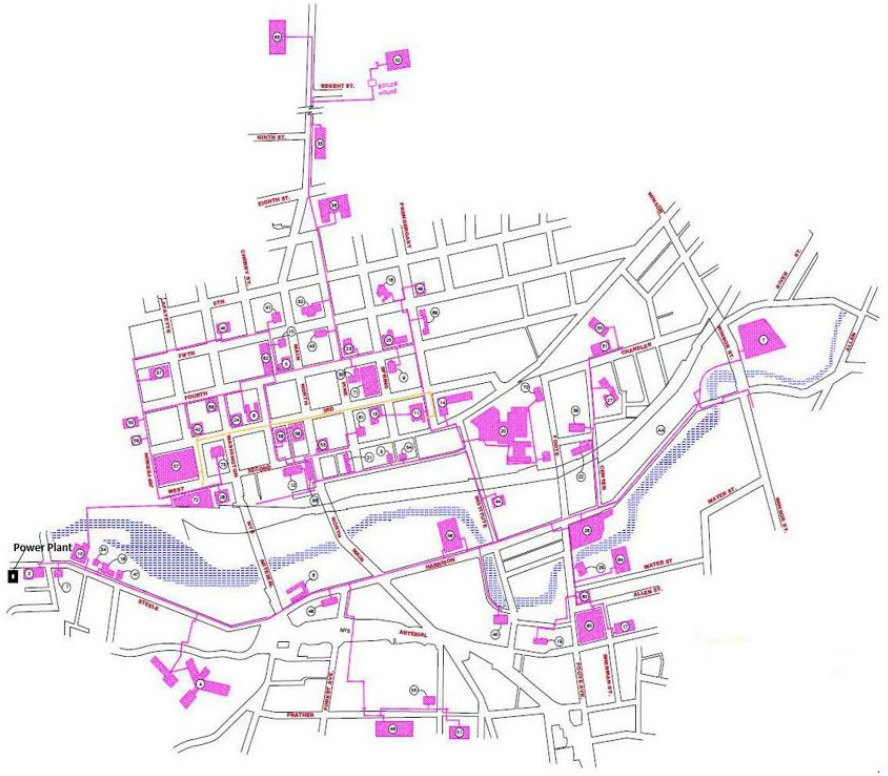


Figure 3: The Jamestown, N.Y., district heating customers are interconnected. Courtesy: Joseph Technology Corp.

The installation of the pilot system created a public awareness, which, coupled with the marketing activities, replaced the initial skepticism with enthusiasm for district heating and its benefits. The marketing aspects of system development in the city of Jamestown involved the combined efforts from the mayor's office, the board of public utilities, other city officials and the consulting engineer.

Numerous public and private meetings were scheduled with prospective core customers to educate them and discuss the advantages of district heating for their buildings. A marketing campaign through public and private organizations, newspapers/magazines, radio and television was used to establish a public consciousness and acceptance, offering evidence through the operation of the pilot system.

The existing structure of the board of public utilities presented a unique opportunity for the city to institute a district heating system that is fully responsive to the interest of the city, with only limited additional procedural, administrative and managerial costs. Important factors in the selection of municipal ownership included the federal and state tax-exempt status and the customer acceptance and trust of municipality.

System economics

The positive economic analysis results served as the cornerstone for the development of the Jamestown system. The economic analysis was performed from the viewpoint of municipal ownership, using its distinct advantages. The operating expenses comprise replacement electricity costs, pumping costs, operations and maintenance personnel, O&M materials and steam costs. The replacement electricity cost is charged against the district heating system to compensate for the reduction in electrical output caused by the district heating steam extraction requirements.

It was recognized that during initial major capital investment years, the cash flow will be negative and breaking even when a critical number of customers were connected. Figure 4 presents the net operating income of the district heating system during the system existence over approximately 35 years.

In the context of municipal ownership, the normal source of funding for a district heating project is obtained through the issuance of long-term revenue or general obligation bonds. The phase one development of the Jamestown district heating system, involving the institution of a pilot system, was financed with short-term bonds. The later phases were financed with long-term bonds, including the refinancing of the first phase.

CHP system benefits

The system benefits include customer savings, environmental advantages, demand-side management application and potential for city economic revitalization.

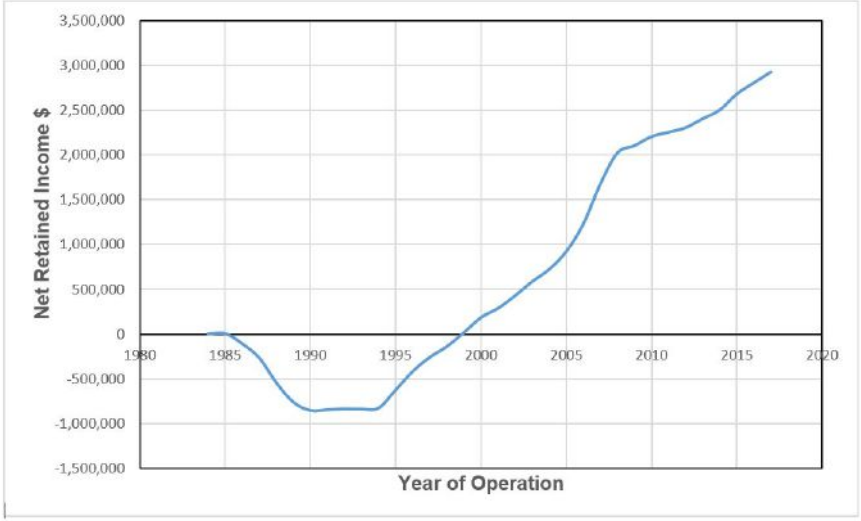


Figure 4: The net retained income from the district heating system shows the past 35 years. Courtesy: Joseph Technology Corp.

The savings of district heating customers versus the self-generation cost of heat is 30% on average. The savings rate increases with any increase in the price of fuel. Customer savings are expected to rise in the future as the system grows with minimal capital investment.

In addition to economic development benefits, the city of Jamestown receives from the district heating system annual contribution in lieu of taxes. For the history of the system, the city has received from the system revenue about $2.2 million in lieu of taxes.

The resulting fuel efficiency of the system resulted in lower emissions and consequently reduced environmental pollution. The continuous and efficient operation of the CHP plant reduces the carbon monoxide and hydrocarbon emissions, which are characteris-

tics of incomplete combustion by customer boilers. To date, 135 individual boilers have been shut down by the customers that were connected to the system.

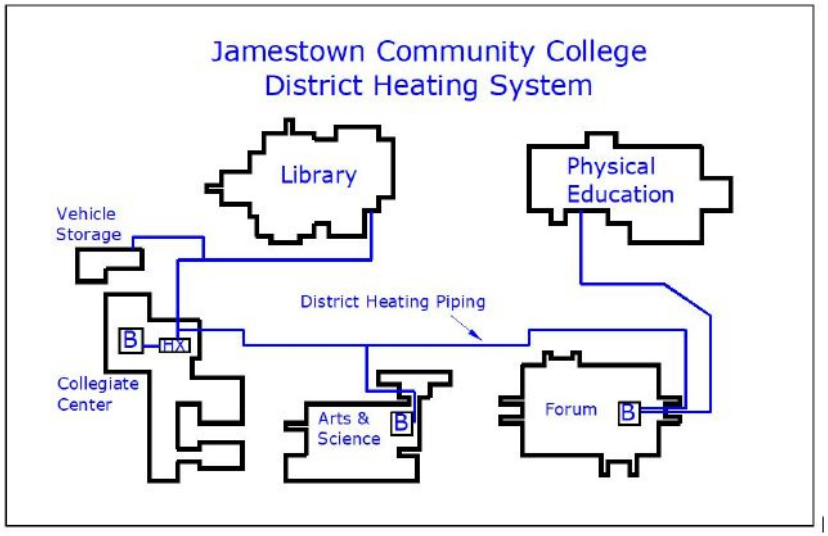


Figure 5: Shown is the district heating system of the Jamestown Community College. Courtesy: Joseph Technology Corp.

The system resulted in reduction of electric peak load of the electric utility. Existing customers with electric heating systems were converted to hot water and connected to the district heating system. This application was significant for the city of Jamestown, considering the winter peaking characteristics of the electrical utility.

Future expansion

The system has been expanded every year. During the past with help of the board of public utilities, the buildings of the Jamestown Community College (located 1.4 miles from downtown) were connected with piping into satellite district heating system (see Figure 5).

The successful development of CHP/district heating in Jamestown is the result of a well-coordinated effort, starting with the system's conception to its operation and growth. The system was implemented in stages. A coordinated effort among the may-

or's office, the board of public utilities and the consulting engineer, produced an effective marketing campaign.

The system ownership and financing capitalized on the advantages offered by the municipal avenue. This enables the city to control the major sources of energy: electricity and heating. The municipal control of these energy sources is used as an economic development tool by the city to attract new business.

Ishai Oliker

Ishai Oliker *is the principal of Joseph Technology Corp., has been involved for more than 30 years in development and design of 25 district heating and cooling systems in the United States, Russia, South Korea and China.*

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