NEW HVAC ZERO MIXING CONCEPT. For Significant Non-renewables and GHG Emissions Reduction on Residential, Commercial, Institutional Real Estate Assets and Light-Industrial Processing.

An Application White Paper from Denering Berrio – DBBS Technology – February 28, 2020

ABSTRACT: *Calgary's local climate is already changing. Between 2005 and 2017, Calgary's overall greenhouse gas (GHG) emissions showed an upward trend of 16%*[1] *(2.5 Megatonnes - Mt CO_2e), from 15.8 to 18.3 Mt-CO_2e. GHG reduction targets of 20% below 2005 levels by 2020*[2] *seem far from achievable. Such trends demonstrate that our current trajectory poses risks to our economy, environment and collective health. In 2016, 62% of the total greenhouse gas emissions community-wide were the result of heating, lighting and power demands from buildings, with emissions split for commercial at 43%, residential 39%, industrial 14%, and institutional at 4%. The need to create better government incentive programs and to develop new breakthrough HVAC retrofit technology for building energy efficiency is badly needed. DBBS proposes a new disruptive "ZERO MIXING" concept and patented SPLIT BUFFER TANK-SBT, which offers a significant opportunity for building thermal improvements that can help correct the current course on GHG trend and reduce dependability on non-renewables. This paper addresses the application of the new HVAC system "ZERO MIXING" design approach that, in combination with improvements in operational practices, can eliminate the gap between intended design and current building performance. It also explores the economic benefits of shifting from the existing technology for building heating and cooling.*

The Market

Calgary's local climate is already changing. Between 2005 and 2017, Calgary's overall greenhouse gas (GHG) emissions showed an upward trend of 16% (2.5 Megatonnes - Mt CO2e), from 15.8 to 18.3 Mt-CO2e. GHG reduction targets of 20% below 2005 levels by 2020 seem far from achievable. Such trends demonstrate that our current trajectory poses risks to our economy, environment and collective health. In 2016, 62% of the total greenhouse gas emissions community-wide were the result of heating, lighting and power demands from buildings, with emissions split for commercial at 43%, residential 39%, industrial 14%, and institutional at 4%.

Upgrading Calgary's large-building infrastructure for energy conservation enhancement after initial construction is not often considered, mostly due to the perceived low energy-efficiency benefits of existing HVAC retrofitting options. The benefits are usually ambiguous and expectations vary widely depending on the type of retrofit and the return on investment (ROI). Decision makers are always concern with the large upfront capital needed for installations and believe that energy retrofits are too expensive with long payback and low ROI. Retrofits' ROI depend on many variables that include the current state of the building, specific technology implemented, and the availability of local and federal government financial incentives. The most common tools used today for building energy conservation include energy efficient technologies for heating and air conditioning, insulation improvements, and lighting. More expensive retrofits include solar-PV/solar-thermal, geothermal systems, and Cogeneration-combine Heat and Power (CHP).

The need to create better government incentive programs for energy efficiency and to develop new breakthrough HVAC retrofit technology for building energy efficiency is badly needed.

The ZERO-MIXING/Split Buffer Tank Proposition

DBBS offers an innovative, low-risk energy-efficient solution with proven outstanding results. DBBS' patented Spit Buffer Tank (SBT[3])/thermal storage reservoir, and the supporting ZERO-MIXING concept, improves overall building HVAC-system thermal efficiency by up to 50%, system availability and operability, reduces equipment maintenance and boosts installed heating and cooling production capabilities. Because it maximizes buildings' AFUE[4], system integration can help reduce consumption of

[1] *Calgary-2018 Climate Resilience Strategy/ http://www.calgary.ca/UEP/ESM/Documents/ESM-Documents/Climate_Resilience_Plan.pdf*
[2] *Calgary Climate Program/ http://www.calgary.ca/UEP/ESM/Pages/Energy-Savings/Climate-Change.aspx?master=old*
[3] *D. Berrio, "Heating or Cooling System Featuring a Split Buffer Tank", Canada CIPO-patent CA2701528, 2012. United State USPTO-patent US8997511, 2015.*
[4] *Annual Fuel Utilization Efficiency. In short, the AFUE indicates, for each dollar spend on energy for heating by gas, oil, or another fuel, just how much of it shows up inside the occupied space of the building as heat.*

costly non-renewables resources, minimize CO_2e emissions and improve business cash flow from periodic maintenance cost and carbon trading opportunities.

The newly patented SBT, and the ZERO MIXING concept it embraces, is an HVAC design and operational approach with a different systemic perspective. Its application looks into the heart of existing HVAC systems and provides technical solutions to an unchecked number of deficiencies, which greatly impair thermal operation of heat plants, chiller systems, building hydronic and terminal equipment. Four paramount concepts, only achievable with integration of SBT, that favour the highest HVAC-system efficient operation include:

- water mixing elimination from building heating primary and secondary system loops (or primary-only systems), Domestic Hot Water (DHW) and chilled water production,
- continuous boiler operation at the highest Steady State Efficiency Test (SSET) conditions,
- system thermal-mass addition that favours temperature control for more stable operation, even on HVAC primary-only systems,
- primary and secondary system loop seamless hydraulic coupling/ decoupling, which allows independent boiler heat loading from building heat distribution (also applicable to chilled water production).

After incorporating the ZERO MIXING concept and retrofitting SBT into new or existing HVAC systems or industrial thermal processes, new technology adopters can expect the following significant benefits.

Building Heating Solution

- Improve system energy efficiency (AFUE) up to 50% on conventional HVAC systems,
- Increase system thermal energy efficiency (AFUE) up to 10.12% from a truly steady condensing operation,
- Increase system thermal energy efficiency (AFUE) up to 30% by complete elimination of boiler short-cycling,
- Double heating and cooling plant capacity with minimum added CAPEX,
- Reduce operational maintenance cost due to boiler over-firing/cycling, very common in poorly designed boiler plants,
- Reduce up to 40% HVAC related electricity usage (16% of building energy cost) from pumping and air handling terminal units,
- Increase productivity and output quality on industrial batch processes that depend on thermal capacity,
- Improve operations' cash flow by reducing the use of non-renewable resources, associated carbon tax levy and CO_2 emissions trading,
- Reduce oversize equipment for new facilities – heating, ancillary equipment, pumping distribution and piping network sizing (on both primary and secondary loops), and lower capital investment cost, as well as future energy bills and maintenance costs relevant to operations.

Domestic Hot Water Solution

- Double hot water production capacity by replacing existing CBT/DHW with the new SBT,
- Attain 30% higher efficient (SSTE) operation with SBT/DHW condensing-boiler system interaction,
- Optimize hot water capacity with a new SBT on-stream control overcoming inefficient hotwell temperature censoring on conventional commercial tanks,
- Reduce boiler wear and tear maintenance costs caused by short-cycling,
- Allow seamless building-heating/DHW operation. Many building heating/DHW integrated systems impose DHW high-temperature requirements to the building's secondary heating system, forcing boilers to continuously operate on non-condensing mode,
- Reduce CO_2e emissions from boiler-DHW inefficient operation,
- Improve cash flow opportunities from reduced non-renewable consumption.

Thermal Solar Solution

- Maximize panel solar adsorption. SBT thermal storage/ZERO MIXING concept integration into HVAC-solar operation maximizes panel energy output at any outdoor condition, increasing solar fraction and therefore reducing supplemental boiler heat,
- Minimize system-hydronic and pumping equipment oversize on newly designed facilities, slashing capital investment cost by half, and improving project feasibility. SBT integration enables higher temperature system/storage differential ΔT≈ 40°C, compared to customary ΔT≈ 10°C/20°C.

CHP Solution

- The SBT/ZERO-MIXING concept integration into the CHP-storage system improves overall plant thermal efficiency by eliminating heat-transferring diminishing-returns due to water mixing during the reheating and storing process operation,
- Since CHP produces both heat and power simultaneously, with daytime power demand usually offsetting heat energy demand periods, efficient thermal storage needs to be readily available during daylight power generation hours. SBT allows cogeneration by-product excess heat to be efficiently stored at a much higher temperature differential, offering larger thermal mass (with greater opportunity for energy capture) than a similar commercial tank with the same dimensional characteristics.

Industrial Applications

SBT improves batch process thermal efficiency by eliminating water mixing during storage and release operation. This alone can greatly increase process output economy in industrial settings that are so dependent on heat-production processing and storing. Suggested SBT and flat-plate heat exchanging configurations favour more efficient full force-convection heat-transfer operation with much higher temperature differential between exchanging fluids (for greater energy-density transportation), doubling the thermal storage capacity of a conventional tank.

ZERO-MIXING and SBT Concept and Technology

Despite ASHRAE's[5] continuous effort to prototype and experiment with new resources that integrate science and technology into HVAC buildings for higher performance and knowledge, design fundamentals are still being challenged by the gap between intended design and actual building HVAC energy performance. A continuous engineering struggle exists to develop the ultimate HVAC system that can effectively integrate energy production with distribution. This is the case for modern HVAC boiler systems (see Figure 1) in which condensing boilers placed at the heart of the system, certified with 92%-95% efficiency ratings, once integrated into the HVAC network are forced by hydronics to display an erratic behavior with unexpected consequence on overall system's thermal performance. Before being sold in the North American market, condensing boilers are certified under ANSI/AHRI Standard[6] through a rigorous Steady State Efficiency Test (SSET). SSET certified efficiencies become the bases for boilers' brand technical information and set the stage for product market competitiveness, ***even though test conditions do not properly relate to real-life operations and are rarely achievable***.

Along with SSET requirements and real-life operation disparity comes the application of engineering short sighted fundamentals conveying the idea that specifying a highly efficient condensing boiler, modern ancillary equipment, and state-of-the-art Building Management System (BMS) guarantees the overall system high performance. Analysis results from sites has proved that ***the greatest system counter-efficiency is not equipment configuration, hydronic connectivity, or controlling, but mainly water mixing.***

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[5]American Society of Heating, Refrigerating and Air-Conditioning Engineers https://www.ashrae.org/technical-resources/ashrae-handbook
[6]http://www.ahrinet.org/App_Content/ahri/files/standards%20pdfs/ANSI%20standards%20pdfs/ANSI.AHRI_Standard_1500-2015.pdf, Section 5.3.5.2.

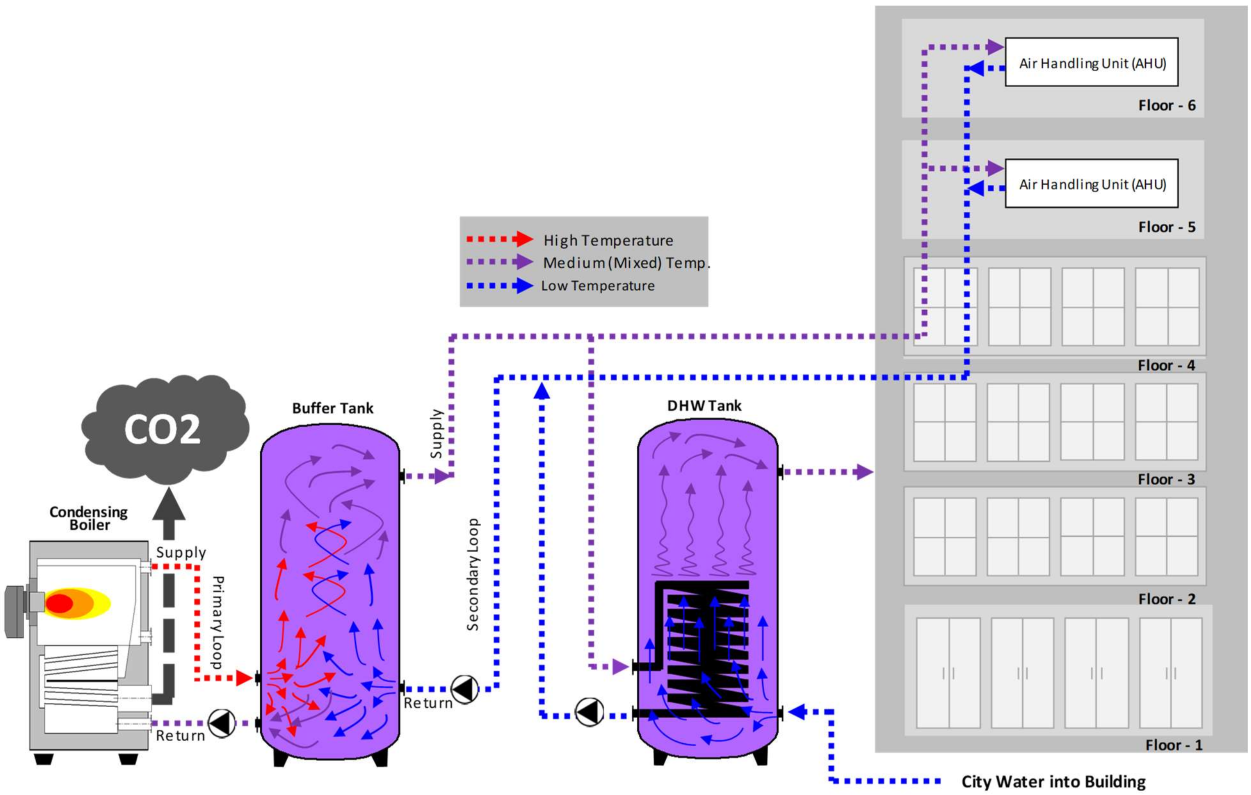


Figure 1: Typical Building HVAC System (Heating + DHW)

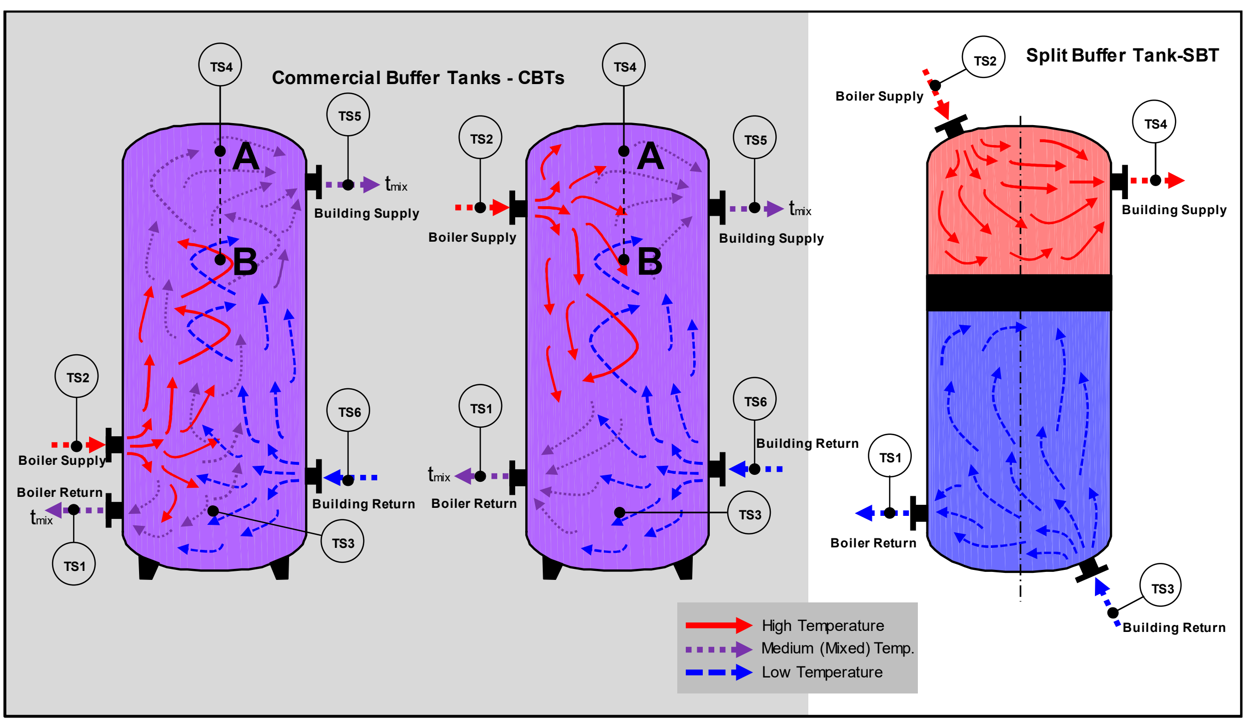


Figure 2: Commercial Split Buffer/Split Buffer Tanks Prevailing Mixing Flows

With the exception of the primary-only, most systems today are configured with a primary loop to reheat circulating water from the buffer to the boiler, and a secondary loop to supply hot water from the buffer to the building and warm-water back to the buffer. The lack of a mechanical barrier to control the encounter of both flows inside hydronics and buffers allow water mixing to happen. It is in this process that mixed water flows are directed to unintended HVAC components with different entering water temperature requirements jeopardizing the efficiency of the equipment and the system as a whole. Including the HVAC primary-only system (see Figure 4b), all condensing-boiler HVAC systems today see their thermal efficiency affected by the same mixing behaviour described above, and operates under the same supply/return characterization curve as the one depicted by Figure 6 (a).

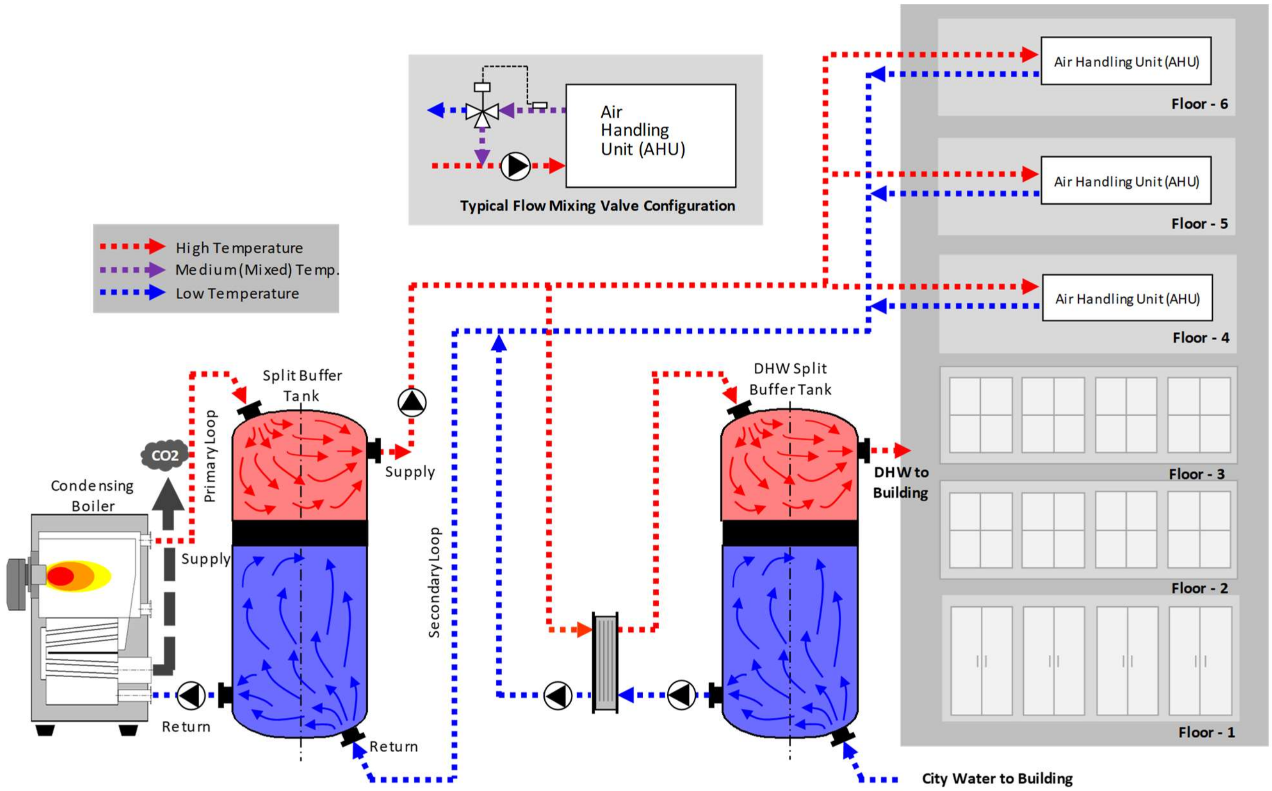


Figure 3: Typical Building HVAC System (Building Heating + DHW) – Split Buffer Tank Operation

HVAC boiler/SBT systems' operation (see a typical split-buffer tank system in Figure 3) eliminates the water mixing phenomenon very common in existing installations today. The ZERO-MIXING concept it uses helps to revise current engineering fundamentals, closing the gap between conceptual design and actual system performance. Like no other devise in the market, SBT integration into a newly developed or old retrofitted system, resolves the boiler-system SSET-test efficiency conundrum and brings real-life performance closer to high-efficiency test conditions.

The system implementation of the ZERO MIXING concept along with SBT integration provides the tools necessary to sustain building HVAC continuous efficient operation (as high as 95% AFUE) by:

- promoting permanent building low-water temperature returns (so necessary for high-efficiency boiler condensation to happened),
- adding the required thermal mass to allow smoother system operation with longer standby periods (eliminating inefficient short-cycling operation),
- maintaining continuous boiler operation at maximum capacity (independent of outdoor or DWH imposing conditions),

- hydraulic coupling/decoupling both system, primary boiler heat generation from secondary system distribution, creating a seamless heat energy loading and distribution with no water mixing or low/high water temperature adverse loop diversion.

SBT technology offers a very distinctive concept that provides intelligence to thermal storage operation. The boiler/SBT system allows water with the lowest possible temperature to be consistently fed back into the boiler (where the coldest water is needed), while hot water with the highest thermal load will always be conveyed to every part of the building for heat delivery (where the hottest water is needed) without any mixing. This thermal separation process is not possible using the current buffer technology or by implementing a primary-only hydronic configuration system (Figure 4 (b)). ***The SBT represents an economical and highly efficient solution for building HVAC retrofitting for existing low-efficiency installations or any new commercial, residential, institutional or industrial HVAC application.***

The SBT/ZERO-MIXING Concept and the Shift from Modern HVAC Boiler Systems

A white paper from Patterson-Kelley (PK) [Short-cycle Prevention for Double-Digit Savings (Part I: Fundamentals & Hydronics) page-6], a well-known commercial boiler manufacturer, goes right to the point by stating that *"Engineers (and most, if not all, boiler manufacturers) often overlook the short cycling effects of their system designs. A distinction must be made between what equipment is capable of doing in the test lab and what a system allows it to do in the field. It is clear to us at Patterson-Kelley that many, if not most, systems force boilers to short-cycle because of the way the hydronics and controls are designed. There are deep flaws in the way the industry thinks about piping and control (and this applies with equal force to the boiler manufacturers). We consider five older but common piping arrangements to illustrate the point. We then turn to what is being promoted by at least two manufacturers today as the state-of-the-art.* ***All are flawed from the standpoint of engineering fundamentals, and a new approach to boiler plant design is clearly called for"***. Figure 4 and 5 (a) illustrate three of the most common arrangements the author is referring to in the paragraph above.

Figure 4 (a) shows a common arrangement for low-mass boiler plant with individual boilers operating on a primary loop and an independent pump serving a secondary loop. Figure 4 (b) shows a primary-only system where the boilers are piped in parallel and accept whatever flow the system requires. Boilers have modulating burners with very good to excellent turndown characteristics and are designed for condensing service.

Figure 5 (a) shows a suggested PK improved design with the addition of a buffer for thermal mass supplement and better temperature control. Various variable-speed boiler circulators serve the boilers and secondary variable speed pump servicing system loads. The flow paths cross and mix in the buffer tank and, according to PK, provide an ideal place for measuring the system water temperature. 5 (b) depicts the new SBT system configuration, with Pump-1&2 servicing the primary and secondary system and individual injection pumps feeding the load into each floor. ***As in the PK suggested design in Figure 5 (a), the SBT design not only improves thermal mass but also eliminating overall flow mixing from the system.***

The Boiler/SBT System Heat Plant Advantage

Boiler-operation characterization curves for the systems shown in Figure 4 (a), (b) and in Figure 5(a) follow the water supply and return pattern depicted in Figure 6 (a). Here the boiler water supply curve is shaped down by the system's Outdoor Reset Controller (OCR[7]), presumably to regulate seasonal output to minimize standby losses and smooth operation. The building water-return curve (also shown in Figure 6 (a)) underlines water temperature back to the boiler. Along the supply curve and at any given outdoor weather condition, boiler capacity is subject to output limitations due to the interaction between Boiler Temperature Reset Differential (BTRD=20°C) and the Boiler High-Limit Switch (usually set at BHLS=82°C). At maximum design conditions (-33°C DB for the city of Calgary), a boiler coming online from standby/setback mode with system water at 30°C, will only be able to raise the system's water temperature to 62°C (82°C – 20°C) for a boiler output reduction of ≈40%. If non-condensing efficiency

[7] *Theoretically, the purpose of outdoor reset is to reduce energy use and cost without sacrificing comfort. The controller lowers the boiler water temperature when the outdoor temperature is warmer and increases it when the outdoor temperature is colder.*

factor is also considered, real boiler maximum operational output will be limited to ≈50%. A cutdown capacity of 45% from claimed boiler manufacturer 95% condensing efficiency.

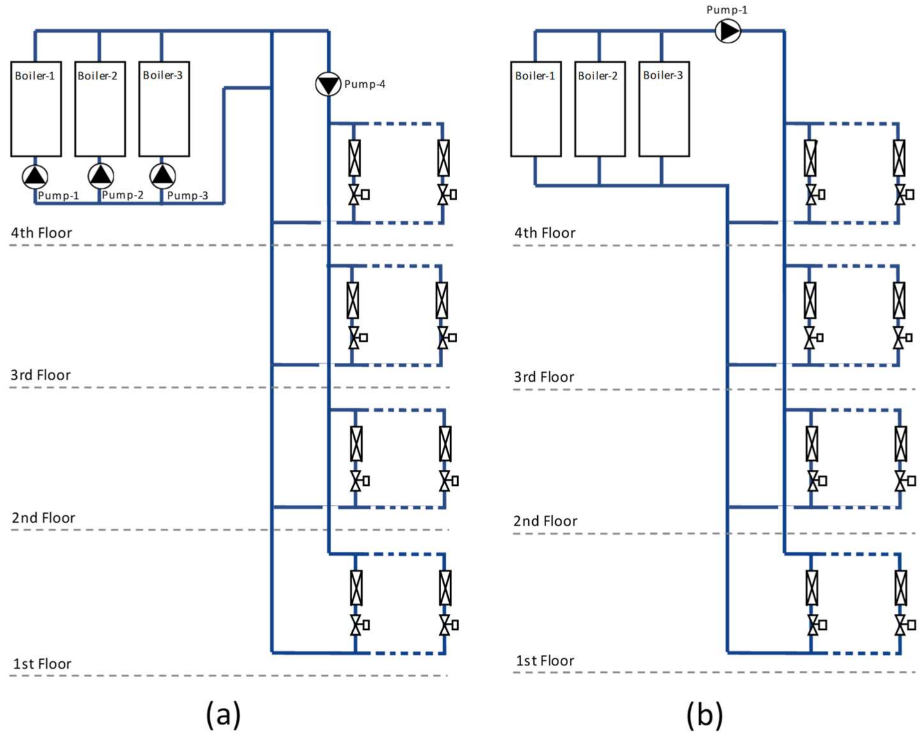


Figure 4: (a) Typical Low-mass HVAC-Boiler System and
(b) Primary-only HVAC-Boiler System (State-of-the-Art)

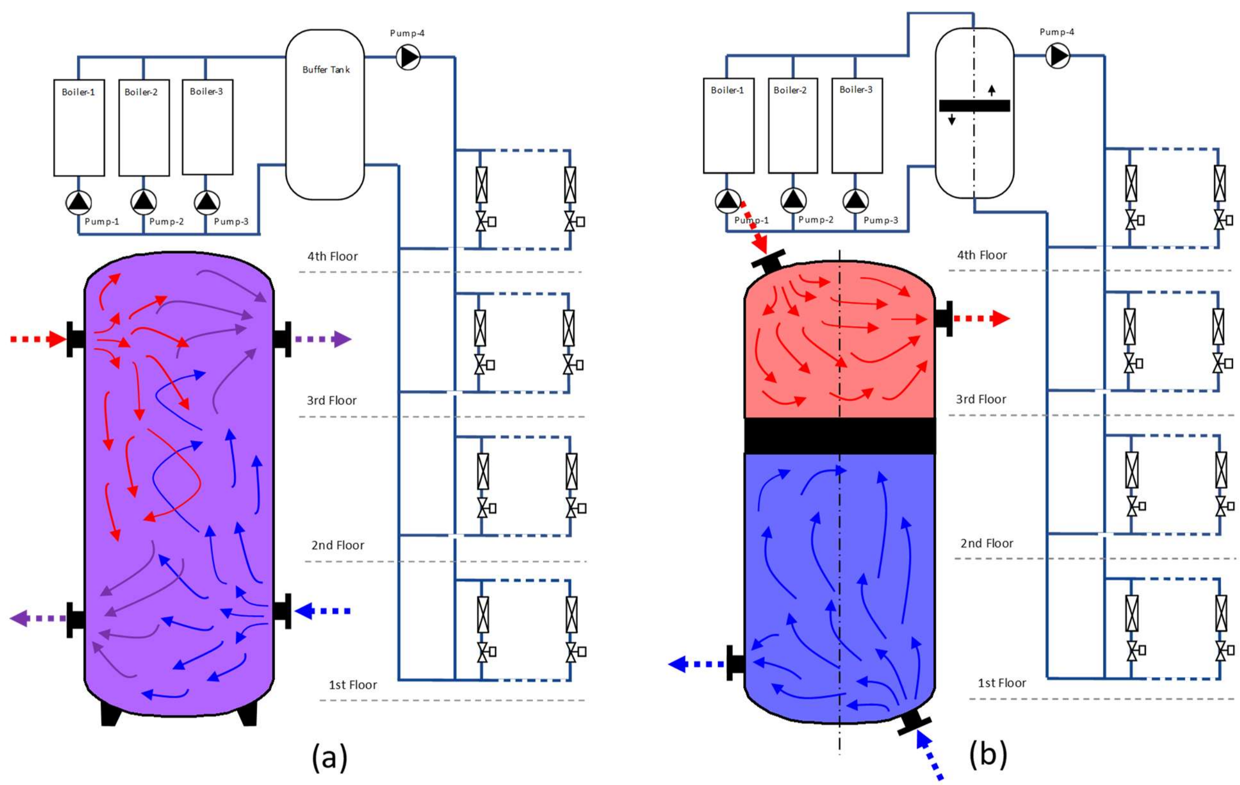
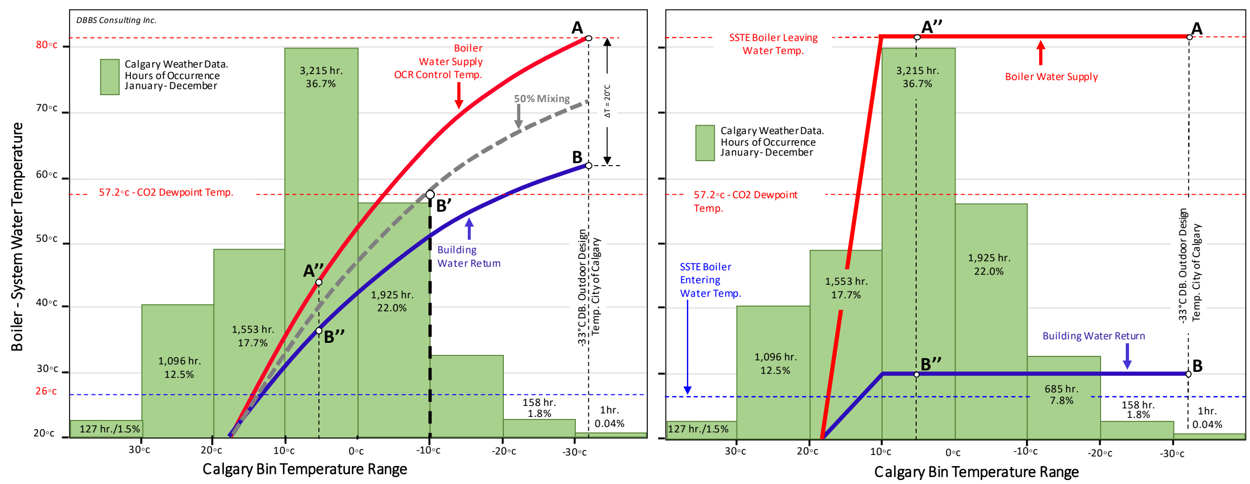


Figure 5: (a) Patterson-Kelley Revised HVAC-Boiler System and
(b) HVAC-Boiler/SBT Arrangement (Newly Developed)

Such operational drawbacks are the result of system hydronics favouring water mixing in the reheating process and the unavoidable boiler-system running scheme depicted in Figure 6 (a), with BTRD=20**°**C. This in turn forces engineers to make uneconomical decisions and overdesign plant capacity in order to makeup for operational deficiencies. In low thermal-mass systems (see Figures 4 (a), (b)), as weather conditions improve, boiler output capacity gets reduced even more as systems ride down the boiler water supply curve, causing boiler plants to operate for longer time at intermittent runs (short-cycling).

*The new boiler/SBT system shown in Figure 5 (b) runs under a very different water supply and return flat patter (Figure 6 (b)) that maintains a constant 82**°**C water supply while returning 30**°**C water temperature for any given outdoor temperature. Since return water is always maintained below 57.2°C, boiler's performance emulates SSET parametric conditions leading to much higher annual system AFUE values. Boiler's maximum capacity output together with boiler performance is always maintained under any given weather condition.*



(6a) (6b)

Figure 6: (a) Modern Boiler-System Water Temperatures Operation and
(b) ZERO MIXING Boiler-System Water Temperature Operation

Figure 7 compares boiler delivery performance by superposing the boiler/conventional system operations chart onto the newly proposed boiler/SBT system chart. Fraction-capacity (fc) graphical comparison, at -33°C DB- temperature design (bin -30°C/-40°C weather conditions), shows fc (fc=CD/AB) to equate 2.5 leading to the conclusion that by *integrating the new SBT/ZERO MIXING concept into an old installed HVAC system's heating plant, the capacity more than doubles, enabling boilers to reduce time operation with longer standby periods. SBT/ZERO MIXING retrofits improve cash flow operation from fuel savings, carbon tax levy reduction and by minimizing maintenance boiler costs.*

At milder weather conditions (fc [fc=C'''D'''/A'''B'''=6]) fc six-folds, providing an opportunity for even longer boiler downtime periods with greater savings. During these downtime periods, the heat supply remains available to the building and DHW system via SBT storage. SBT loads will be released to the building until it is fully exhausted, and the efficient loadings process reinitiates again. Figure 7 also shows that the boiler/SBT system capacity is not controlled or diminished by the OCR controller at any outdoor condition and that SSET operational pattern remains always steady.

The SBT/Building Thermal Mass Advantage

In every HVAC system today (see Figure 4 (a) and (b) and Figure 5 (a)) design heating loads almost never occur (≈2% of year operation), and boilers spend nearly 6,700 hrs (80%) of operation running at partial loads (between bins 20°C/10°C to 0°C/-10°C) to overcome smaller building seasonal heat loses due to milder weather conditions. Since in the absence of thermal buffers, stored piping water thermal-mass is the last resource for a system starving from heat, the remaining heat in the hydronic system water is rapidly withdrawn until the water temperature condition falls below the boiler's controller setpoint, forcing it to fire. At mild outdoor temperatures (bin 10°C/0°C, see Figure 7) boilers fire at a fraction of the design load indicated by the temperature differential between points A'''B'''. Such a small output, in comparison with boiler/SBT output determined by point C'''D''', along with the low piping water thermal mass, makes boilers to run in an on-off fashion (short-cycling[8]) for longer time in the process to serve the building loads. Each short-cycle is accompanied by a small pre-purge and a post-purge chimney heat discharge (estimated at 3% to 6% of boiler hourly output). The purge differential (PD) dashed-line in Figure 7 gives an indication of the incremental purging events for the typical PK boiler/CBT system in Figure 5 (a), in comparison with the more efficient boiler/SBT system shown in Figure 5 (b). Note that for the low-mass primary-only system (see the grey dashed line in Figure 7), more boiler on-off runs with additional pre/post-purges will be necessary to deliver the same required building loads.

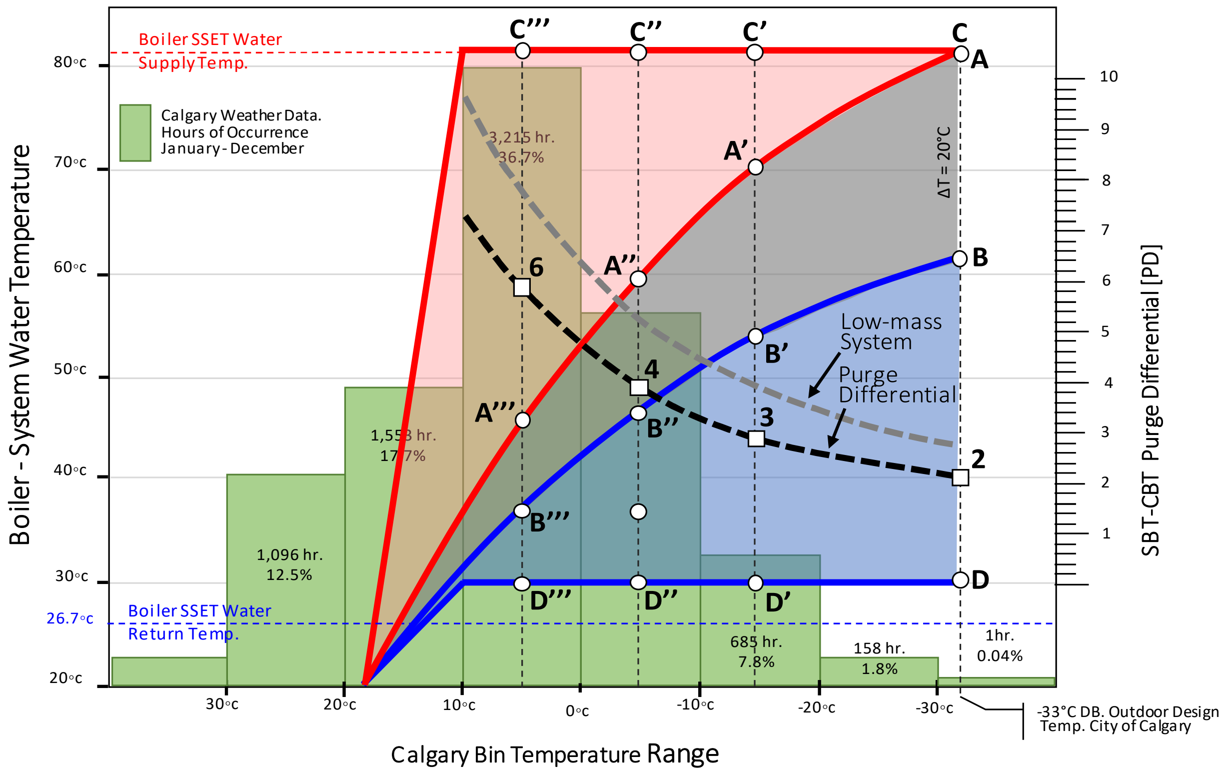


Figure 7: Boiler SBT/CBT Purge Differential Chart

The proposed Patterson-Kelley (PK) HVAC system in Figure 5 (a) suggests the addition of a CBT for thermal mass advantage. Still its buffer-hydronic configuration favours water mixing conditions causing; in this case, limitations to the system's thermal loading operation (see Figure 8 (b), with maximum=53%) in comparison with the boiler/SBT system capacity (of 100%) with no mixing at all (see Figure 8 (a)). Differing from the boiler/SBT system squared loading, the PK boiler/CBT system is characterized by a sluggish triangular thermal-gain pattern evolving overtime as the water supply and return mixes and the temperature raises up to BHLS setpoint during the reheating and building distribution process.

Short-cycling is also the result of system oversize heating plant with poor boiler(s) turndown ratio or an erratic multi-boiler system water temperature controller. In any case, either a low-mass system, boiler oversize, or water temperature controlling issues, loses small in size take a huge toll on annual boiler AFUE percentage efficiency due to their reoccurring nature. *No matter what the case, short-cycling can be eliminated at once with the integration of the SBT/ZERO MIXING concept into any HVAC boiler system. Boiler/SBT maximum-capacity efficient thermal operation provides systems with the necessary hot water for instantaneous building heat demands due to building loses, infiltrations, or domestic hot water needs.*

[8] *Boiler short-cycling consist of a firing interval, a post-purge, and idle period, a pre-purge, and return to firing. During these events, the boiler may exhaust through the chimney between 3% to 6% of its hourly boiler useful output.*

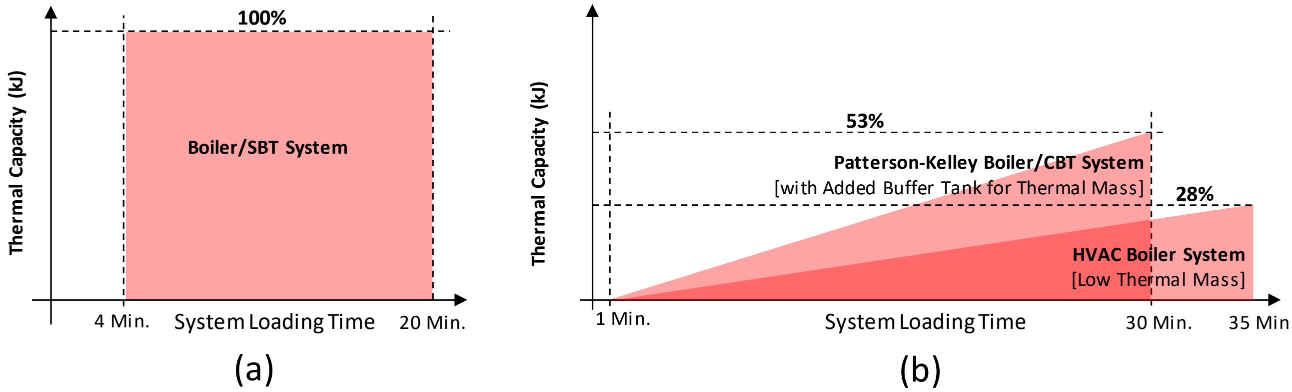


Figure 8: (a) Boiler/SBT-system Thermal Loading Build-up and
(b) Patterson-Kelley/Low Mass System Thermal Loading Build-up

Minor SBT standby loses from higher temperature operation will not affect overall HVAC system efficiency since they remain inside the building envelop instead of continuously being exhausted through the chimney as a result of short-cycling. Even though water-mixing elimination seems to be the key element for improving efficiencies, it is the combination of both thermal mass addition and the ZERO MIXING concept that really shields systems from the operational deficiencies indicated above.

Data from laboratory test[9] on similar SBT/CBT twin systems proved that at boiler maximum capacity runs, the boiler/SBT system outperformed the boiler/CBT system output by 47% and delivered a 100% load at a fraction of the time (17 minutes, see Figure 9). The boiler/CBT system had to perform a second 30-minute run to match the boiler/SBT output, triggering two additional/differential purges in the process. *The boiler/SBT system ZERO MIXING emulation test proved that it is possible to provide the system with continuous boiler high-temperature water output and obtain in the process a low-water return back to the boiler for reheating while maintaining SSET efficient operation.*

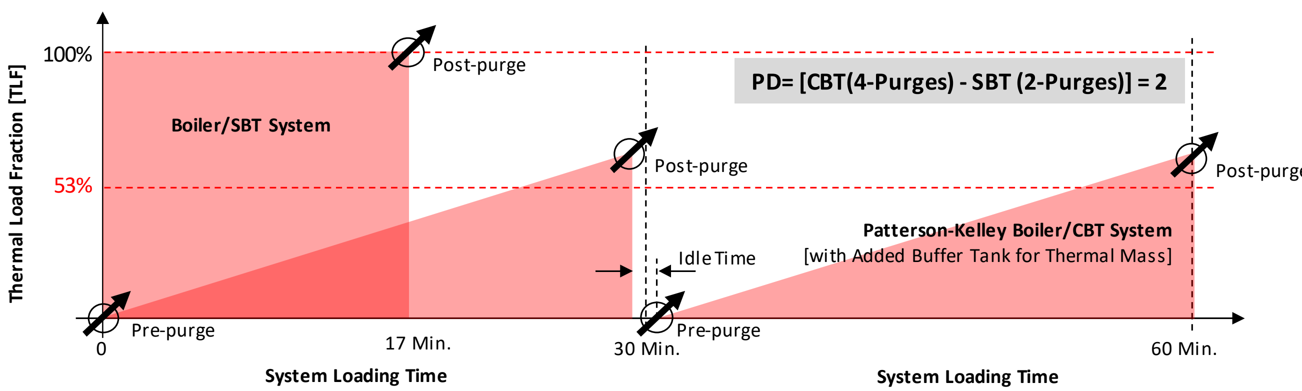


Figure 9: Boiler SBT/CBT System Thermal Loading Profile

The Boiler/Building System Low-Flow Advantage

Current HVAC design fundamentals on condensing boiler-systems reinforce the practice of boilers' output settings that call for BTRD=20°C reset-temperature differential. Despite suggested advantages, a previous SBT/CBT test demonstrated that reset-differential limits hot-water production capacity while forcing the system to operate at unnecessary pumping higher-flow volumes on both primary and secondary loops. A low HVAC boiler-system temperature differential operation also diminished water conditions for optimum heat output from ancillary equipment (AHU heating coils, VAV-box heating coils, radian slabs

[9] ***"Split Buffer Tank Prototype Testing," by SAIT-Green Building Technology, 2017.*** *SBT prototype for the Canada CIPO- CA2701528 /US USPTOUS8997511 patented invention; Spit Buffer Tank (SBT), was built and tested by SAIT Green Building Technology Division (GBT) with the support of Alberta Innovate Technology Futures (AITF). The thermal test included a number of experimental buffer heat loading scenarios developed with the purpose of evaluating SBT thermal efficiency improvements over a typical commercial buffer tank (CBT), when connected to a HVAC Condensing Boiler system. The test data gathered helped to support patented concepts on water mixing and its detrimental effect in overall HVAC system efficiency.*

heating, hot water baseboards, snow-melt system or any other devices used for heat delivery). Such limitations force secondary system terminal units not only to work harder but also for longer periods of time to provide building comfort; or in the case of industrial setting, limiting optimum process setpoint conditions (sacrificing production output and quality).

Advantages offered by the water-mixing elimination allows the boiler/SBT system operation to run at a maximum SSET temperature differential (up to 52°C) on both primary and secondary loops, resulting in reduced pumping and air-handling flows without sacrificing boiler, or AHU, VAVs max output. *The new boiler/SBT system low-flow/high-temperature differential design offers to retrofitted system substantial savings on electricity bills from reduced pumping capacity and AHU/VAV-box air-fan operation.*

The boiler/SBT system low-flow operation also offers greater savings opportunities on capital investment for new facilities with the reduction of otherwise oversize equipment, on both primary and secondary loops. Reduced cash flow from operation on lowering future energy bills and maintenance costs will also be improved.

On the HVAC Solar Thermal field, low-flow/high-temperature differential operation (ΔT≈ 40°C, instead of customary ΔT≈ 10°C/20°C) can be the answer to lower initial capital investment on pumping equipment and hydronics, and also reducing pumping energy costs. Proposed new ΔT≈ 40°C running strategy has the potential to improve payback periods from 17 years to 6-8 years.

The Boiler/Building System Control Advantage

There are many ways to control a boiler and the boiler controls can be layered. A boiler's own controls can be set for standalone operation to maintain desired boiler setpoints, and also can be linked to a more complex Direct Digital Control (DDC) system for a multi-boiler multi-stage with more complex controlling operation. Customary use of DDC-OCR controls to manage boiler output, coupled with temperature controlled variable flow pumps to produce low temperature water return for boiler condensing opportunities, always result in water mixing in the supply heater. No matter what strategy is used, multi-stage boiler lead/lag, boiler lead/lag with demand or boiler multi-pump rotation/operational sequencing, boiler(s) at some point during operation are forced to overfire (short-cycle) due to mixing. *SBT system integration and its on-stream reading, with sensors location TS1/TS2/TS3/TS4 at the inlets/outlets of the tank (see Figure 2), allows accurate input/output temperature measurements and signaling back to the boiler(s) and building's pumps, eliminating therefore problems associated to manifold temperature sensor misreading. Since boiler supply and building return flows are contained within the SBT, water mixing will never occur nor the associated signaling problems.*

In the case of the system buffer in Figure 5(a), or any DHW systems, CBTs prevailing mixing flow patterns (see Figure 2) have the greatest impact on buffer loading capability and the excessive dollar spend in water heating operation. Typical upper sensor "A or B" locations induce reading errors/delays due to instantaneous signaling on the isotherm rather than on the average temperature of the tank, understating or overstating the actual buffer load. In either case, boiler will always overfire trying to satisfy system demand. Proper positioning is a determining factor in attaining maximum buffer thermal capacity due to boiler dependency on sensor signaling for firing control. A sensor location too high (A-position in the tank) may force boilers to over-fire in order to reach temperature setting. Too deep into the tank, such as B-position, may reduce buffer volumetric/thermal capacity, increasing boiler cycling for particular loads. Finding the most appropriate spot is an impossible task, especially in systems where heat demand moves through a wide range of seasonal temperature variations, causing the buffer to operate from 26°C during summer up to 62°C during winter. In the case of DHW, to maintain the 49°C ± setting.

The SBT concept eliminates the CBT disadvantages noted above by using on-stream reading with sensors location TS1/TS2/TS3/TS4 at the inlets/outlets of the tank. This allows instantaneous accurate temperature measurements and eliminates problems with CBT TS4 censoring lagged readings, favouring better temperature control and storing greater thermal mass, for more stable energy production and distribution. On the flow dynamic management, SBT separation disk helps isolate primary and secondary loop streams from mixing inside the tank, doubling DHW capacity while reducing non-renewables cost and the associated CO_2 emissions. SBT water storing temperatures can reach up to 82°C compared to 62°C for the CBT.

Final Consideration

HVAC Engineers today are confronted with the daunting task of designing systems to perform at maximum capacity that can also excel at part-loads. But, under existing design practices and the current state of technology for system piping networks [hydronics]; favoring system Water-Mixing conditions, that is not possible. Water-Mixing in system hydronics arises from the encountering of boiler(s) hot-water supply with system colder-water returns. Increasing Temperature in resulting mixed-tempered-water is the major threat to boiler performance operation, while poor System-Thermal-Mass and its effect on boiler short-cycling is the real culprit of system efficiency [measured by the Annual Fuel Utilization Efficiency - AFUE]. Short-cycling is not a simple phenomenon and it arises from the interactions that take place between two or more of the processes described above. There are system conditions that arise from optimal performance of the heating system's terminal units and/or Domestic Hot Water [DHW], and there are system conditions that are optimal for efficient boiler(s) performance. Under the current state of technology, these two set of conditions are rarely, and perhaps only accidentally, the same. What is optimal for the former is usually not optimal for the latter one, and vice versa. Attempts by designers to accommodate the needs for the boiler when designing system hydronics can, and often do, compromise the performance of their systems. Ignoring the needs of the boiler creates short-cycling, and the energy lost from it often serves to undo the gains made by state-of-the-art system designs. A designer must acknowledge that in reality there are two systems being designed – the building heating system and the boiler plant – and that their requirements are always different, usually different enough to make a difference almost irreconcilable.

The Split Buffer Tank [SBT]; and the Zero Mixing concept it encompasses, articulates the mismatch on water-supply and water-return temperatures in interconnecting system loops. SBT acts as the perfect decoupling/coupling loops point where both boiler(s)-supply high-temperature-water and building-return low-temperature-water flows can confluent and be diverted into the right path. In system hydronics; this change alone, allows boiler(s) to run at Steady States Efficient operation while providing building terminal units and the DHW with the optimum heat input for occupant comfort and units performance.

On industrial settings; dependable on batch process heating, water mixing elimination removes heat capacity bottle-necking, boost heat-plant-output and improve production quality, greatly impacting business bottom line.

Same Zero-Mixing concept and SBT-tank integration can be introduced to chiller-plants with the same energy saving advantages.

DBBS new technology moves away from the LOW - TEMPERATURE - DIFFERENTIAL concept very common on existing condensing boiler plants/chilled water systems and apply a more efficient model based on "ZERO MIXING and HIGH - TEMPERATURE - DIFFERENTIAL" concept.

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