

WHITE PAPER:

Exploring High Turndown in Hydronic Boiler Systems

Challenges, Benefits & Balancing Efficiency



Abstract: This white paper explores the limitations and challenges of high turndown boilers in hydronic systems. The goal is to identify potential challenges and provide insights for optimizing energy efficiency. While high turndown ratios are praised for their flexibility and potential cost savings, this paper delves into the drawbacks associated with their implementation. These drawbacks can include combustion instability, increased maintenance requirements, and limitations to system performance. By understanding and addressing these potential issues, stakeholders can make informed decisions to maximize the benefits of the boiler system by selecting the appropriate products for their applications.

Exploring High Boiler Turndown



Exploring high boiler turndown: A review of the challenges, benefits and balancing efficiency

Boiler turndown is the boiler's ability to adjust the firing rate to meet demand. Its primary purpose is to match the burner's output to the system's varying heat demand. This technology is one of the major components in optimizing the flexibility and maximizing the efficiency of the heating systems. While a high turndown ratio is often commended for its energy efficiency benefits through load-matching advantages, it is equally important to recognize the potential downsides of extremely low firing rates. These downsides can impact efficiency, reliability, and overall system effectiveness. This white paper explores the lesser-known challenges associated with high turndown ratios in hydronic boiler systems that can affect performance and reliability.

Understanding Boiler Turndown

Boiler turndown refers to the ratio between the maximum and minimum firing rates of the burner. A higher turndown ratio offers significant benefits in terms of system flexibility and fuel economy by allowing the adjustment (modulation) of the firing rate to optimally match the heat demand while avoiding short cycling of the burner. These features of reduced boiler cycling and improved load efficiency, lead to the ability to calculate the firing rate to match the system's demand while providing flexibility to modulate down the firing rate as the demand reduces. This modulation into low firing will ultimately help prevent thermal losses by avoiding cycling. The results of turndown will minimize energy waste in the form of the boiler's thermal heat loss and help achieve optimal fuel usage by avoiding unnecessary cycling. Many manufacturers provide burner turndown options that can range from 2:1 on the

low end and some can even achieve up to 35:1 on the extreme high end.

The U.S. Department of Energy standard recommends a minimum boiler turndown of 5:1 (Purchasing Energy-Efficient Large Commercial Boilers - Department of Energy). The DOE's findings emphasize that most gas burners exhibiting a turndown ratio of 10:1 or 12:1 will operate with little to no additional loss in combustion efficiency in the lower firing rates (Improve your boiler's combustion efficiency - Department of Energy). Venturing into high turn-down systems often requires an increase in make-up air to avoid potential combustion problems in the low fire ranges. While technology may evolve and bring new information, it's currently crucial to consider the potential system and efficiency challenges associated with extremely low firing rates when dealing with higher-than-average turndown ratios to maintain overall effectiveness.

Factors Affecting Boiler Turndown Savings

Burner Efficiency and Modulation Range: The burner's ability to efficiently modulate across a wide firing rate range significantly impacts the effectiveness of boiler turndown. While high turndown ratios provide flexibility and efficiency benefits, achieving stable combustion at extremely low firing rates can be challenging. Excess air is added to low fire ranges to ensure complete combustion and help prevent the formation of carbon monoxide and soot. With the excess air induced, the flame temperature can be lowered as an increased amount of heat is lost through the excess air and out through the flue. The potential flame instability may lead to inefficient fuel combustion, increased emissions, and compromised system efficiency. Additional measures, such as increased makeup

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air and combustion controls, and sensors may be necessary to maintain correct and efficient combustion.

Increased Maintenance Requirements: As turndown ratios increase and the need for added excess air grows, the need for regular maintenance and tuning becomes critical to ensure stable and efficient combustion. Low firing rates over extended periods can impact and shorten the longevity of key components such as burners, flame sensors, and oxygen trim sensors. Fouling and corrosion of key components may also arise due to low fire flue gas temperatures and from modulating the burner to match a low delta which can prevent condensing. All of these factors can necessitate the requirement for more frequent cleaning, maintenance, and combustion tuning. In addition, the complexity of the system increases with the need for additional sensors to monitor and control the low fire flame stability. These wear and tear components can include oxygen or mass flow sensors and the need for additional complex computer algorithms to drive the systems.

System Response Time: Due to the intended design to maximize efficiency, the burner response algorithm will have a preferential default to maximize the high turndown ratios by utilizing low fire as much as possible. These algorithms may result in slower response times during rapid changes in heat load. This delay can lead to discomfort or inefficient operation, especially during quick load fluctuations of load occupancy or shifting seasonal weather.

Exploring what is the right solutions to meet the needs:

Calculating the optimal turndown ratio for

the boiler system involves considering several factors related to the specific application and its requirements. The turndown ratio should be chosen to strike a balance between energy efficiency, load flexibility, and overall system performance. Here are the steps to help calculate the optimal system:

- 1) Determine the Maximum Heat Load: Start by identifying the highest heat load that the boiler system will need to handle. This is typically the maximum heating demand required during the coldest weather or the peak load demand for the application.
- 2) Find the Minimum Heat Load: Next, determine the minimum heat load the boiler system will encounter. This is typically the lowest heat demand during milder weather or periods of lower occupancy in the facility. Take into consideration the smallest load of a zone system when determining this.
- 3) Calculate the Load Range Needed: Once the maximum and minimum heat loads have been calculated, the turndown ratio can be determined by dividing the maximum heat load by the minimum heat load. $\text{Turndown Ratio} = \text{Maximum Heat Load} / \text{Minimum Heat Load}$. This will be important in deciding how the boiler or boilers will be needed to respond and manage the load.
- 4) Evaluate System Efficiency: High turndown ratios are generally associated with improved system efficiency, but this might not always be the case. Evaluate the efficiency of the boiler system across the full range of firing rates to understand how the boiler will perform at different loads.

5) Consult with the Boiler Manufacturer: The

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boiler manufacturer can provide valuable insights into the turndown capabilities of their equipment and can make specific recommendations for the application and desired performance. The manufacturer or manufacturer's representative can also provide guidance on the best turndown ratio options for the specific application.

6) Consider System Load Profile: Consider the typical load profile of the facility or application. If the system is prone to frequent heat load fluctuations, a mid to high turndown ratio might be more beneficial to match the load variations.

7) Evaluate Cost Savings: Assess the potential cost savings associated with different turndown ratios. This includes considering and comparing the annual fuel consumption and potential savings while weighing the additional maintenance costs and expected equipment life span and longevity.

8) System Constraints: Be mindful of any constraints in the system, such as combustion stability issues at low firing rates or the impact

on other connected components within the system. How will the circulation of the system integrate with the lowest turndown? Can the system's circulators match the reduced flow for the burners turndown?

9) Explore Multiple Boiler Systems: For example, instead of one large boiler use the options of 3 smaller boilers equaling BTU load. Not only can this option provide better staging, faster response, and improved fuel utilization, but it will also enable an option to provide system redundancy at different capacities. These discussion points can help assess the impact of various factors and optimize for the selection.

By following these steps and considering the aspects of the boiler system as well as the specific load application, the optimal turndown ratio that maximizes energy efficiency and system performance, while ensuring safety and reliability, can be determined. Remember that the optimal turndown ratio may vary for different installations, so it's crucial to understand and tailor the calculations to the specific application.

Summary

While high turndown ratios offer significant benefits, it is essential to address the potential downsides associated with their implementation. Stakeholders can lessen these challenges by employing advanced burner technologies, implementing proper maintenance practices, and ensuring accurate system design and sizing.

Striking a balance between turndown ratios and system requirements is crucial for achieving energy efficiency, load flexibility, and long term system effectiveness. By taking into consideration the limitations presented and adopting suitable strategies, boiler systems with high turndown capabilities can be optimized for improved performance and reliability.

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Additional Reading:

Purchasing Energy-Efficient Large Commercial Boilers - Department of Energy

<https://www.energy.gov/femp/purchasing-energy-efficient-large-commercial-boilers>

Improve Your Boiler's Combustion Efficiency - Department of Energy

<https://www.energy.gov/eere/amo/articles/improve-your-boilers-combustion-efficiency>

Weil-McLain Commercial Boiler Line

<https://www.weil-mclain.com/products/commercial-boilers>

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Zach is a licensed Master Plumber who brings a rich tradition of knowledge and craftsmanship that accompanies a 4th generation tradesman in the industry. Zach has over 30 years of experience in HVAC and piping trades with a specialization in hydronic heating systems.