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Supplemental firing without augmenting air

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As the requirements for cycling capabilities and plant efficiencies have increased, duct burners have adapted to meet these needs. One such duct burner can operate in lower O2 conditions than conventional duct burners without the need for augmenting air, offering plant flexibility with lower installation cost, reduced flame length and better emissions, writes ***Windy Muehleisen***

A typical duct burner fuel skid assembly

Credit: Forney

Recent regulations and market trends are leading the power generation industry away from coal to more gas turbine combined-cycle (GTCC) plants.

GTCC plants previously serving peaking and intermediate power demands are being used increasingly to address baseload needs. This has increased the requirements for cycling capabilities and plant efficiencies. Plants must be designed with maximum operational flexibility in order to dispatch required power when needed.

Maximum flexibility in GTCC plants is necessary to optimize steam production over a wide range of gas turbine loads. Whether increasing steam production for additional power or cogeneration applications, supplemental firing (duct firing) systems are provided for added heat input and system flexibility.

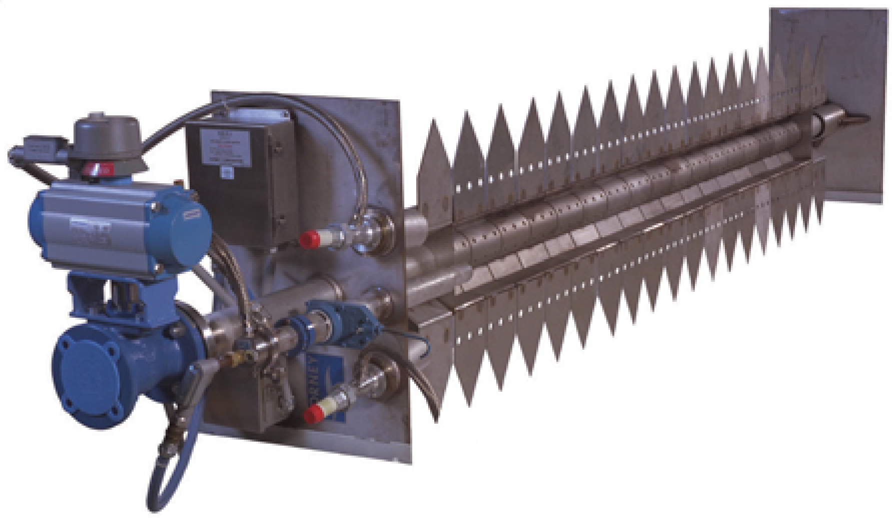
For supplemental firing, duct burners are most often installed within the heat recovery steam generator (HRSG) inlet duct or between the HRSG final and primary superheater/reheater sections (more common in larger GTCC plants).

Runner or grid-type duct burners are the most common design for gas-fired duct burners. The burner elements are inserted through an opening in the HRSG casing and span the entire width of the duct. An element manifold pipe with evenly spaced fuel discharge orifices serves as a fuel distribution conduit.

Outside of the HRSG casing, the duct burner assembly includes a High Energy Spark Igniter (HESI), element junction box, element isolation valve and flame scanner.

During burner operation, fuel gas exiting the orifices mixes with turbine exhaust gas (TEG) to create an anchored flame base. A large portion of the base flame is shielded from the TEG in order to prevent flame blowout by incorporating flame holders (stabilizers). The stabilizers can induce turbulence which, as the flame develops, mixes additional TEG into the flame.

Mixing TEG and fuel in the proper proportion prevents the flame from being cooled too quickly, which would result in higher emissions of carbon monoxide (CO) and unburned hydrocarbon (UHC). This also prevents the flame from being too hot, which can contribute to high NOx emissions.



The adVanatge duct burner assembly showing patented triangular diffusers

Credit: Forney

Reduced flame length is also a benefit of optimum TEG and fuel mixing. As such, the downstream ‘firing duct’ length between the burner and the downstream heat exchanger within the HRSG can be reduced. The firing duct length needs to be long enough to allow for adequate mixing of the TEG and burner fuel to reduce flame lengths and avoid flame impingement on downstream components.

The duct burner diffuser design can greatly influence combustion completion and flame length characteristics. Forney’s adVantage diffuser induces turbulence through its triangular shape, much like an aircraft wing creates ‘wingtip vortices’. This refers to circular patterns of rotating air left behind an aircraft wing as it generates lift. The wingtip vortex phenomenon was applied in the development of the patented design of the adVantage duct burner.

As the flow distribution from combustion turbines is typically uneven, zones of low oxygen will exist which lead to incomplete combustion, longer flames and higher emissions. Shown in Figure 1, the adVantage diffusers induce turbulence, resulting in superior mixing of the turbine exhaust gas.

This minimizes the low oxygen zones and creates a better environment for combustion. The exclusive mixing process produces shorter flame lengths as compared to conventional duct burners reducing downstream duct distance and improving temperature distribution from the burner.

Further, since the vortex streams effectively mix a portion of the TEG into the burner flame at the outside edge of the flame envelope, CO and unburned hydrocarbons from the TEG are essentially eliminated resulting in overall lower stack emissions with the duct burner in service.

With the adVantage design CO emissions are reduced by as much as 80 per cent over conventional duct burners with no increase in NOx. These reduced emissions can help to offset other plant costs such as downstream emission reduction equipment.

One of the challenges of supplemental firing is having enough oxygen to support combustion. As higher combustion turbine efficiencies have emerged, TEG O2 levels have been lowered to less than 12 per cent by volume at times. This low O2 level combined with high temperature TEG is sometimes insufficient as a source for supplemental firing. In these cases, extra O2 in the form of augmenting air must be added.

Augmenting air is supplemental air typically introduced behind the duct burner element. The augmenting air is needed to increase the TEG O2 levels to promote more stable combustion. Introduction of the low temperature augmenting air decreases the resulting temperature from supplemental firing. This leads to an increase in CO emissions compared to systems that do not require augmenting air.

Due to the superior mixing of the TEG associated with the adVantage duct burner design, the requirement for augmenting air can be reduced or even eliminated. Compared to conventional duct burners, the adVantage duct burner requires less O2 for stable combustion at a given temperature.

The Forney adVantage duct burner can operate in lower O2 conditions than conventional duct burners without the need for augmenting air. Removing the requirement for augmenting air eliminates costs associated with delivering the air to the burners. This includes the supply of an augmenting air blower skid, augmenting air distribution manifold inside the duct, and duct work between the blower skid and the distribution manifolds. Additionally, the augmenting air blower motors (typically 100-300 HP) present a parasitic load adding to operating costs. Eliminating augmenting air from a typical 300 MW gas fired combined cycle plant can save some $400,000 in capital costs per unit.

Further, the cost savings include a reduction in the number of burner elements needed if augmenting air is not required and the increased wear and tear on the burner elements associated with adding augmenting air is avoided. Finally, without augmenting air, any associated CO or NOx formation is eliminated.

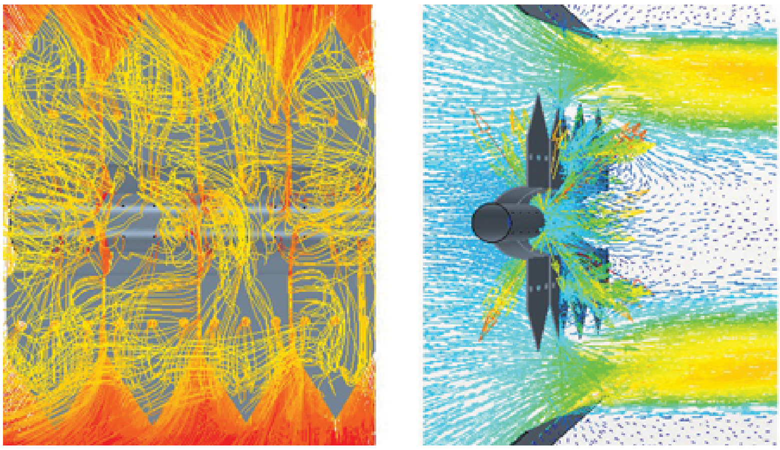


Figure 1. Improved mixing due to adVantage duct burner-induced vortices

Credit: Forney

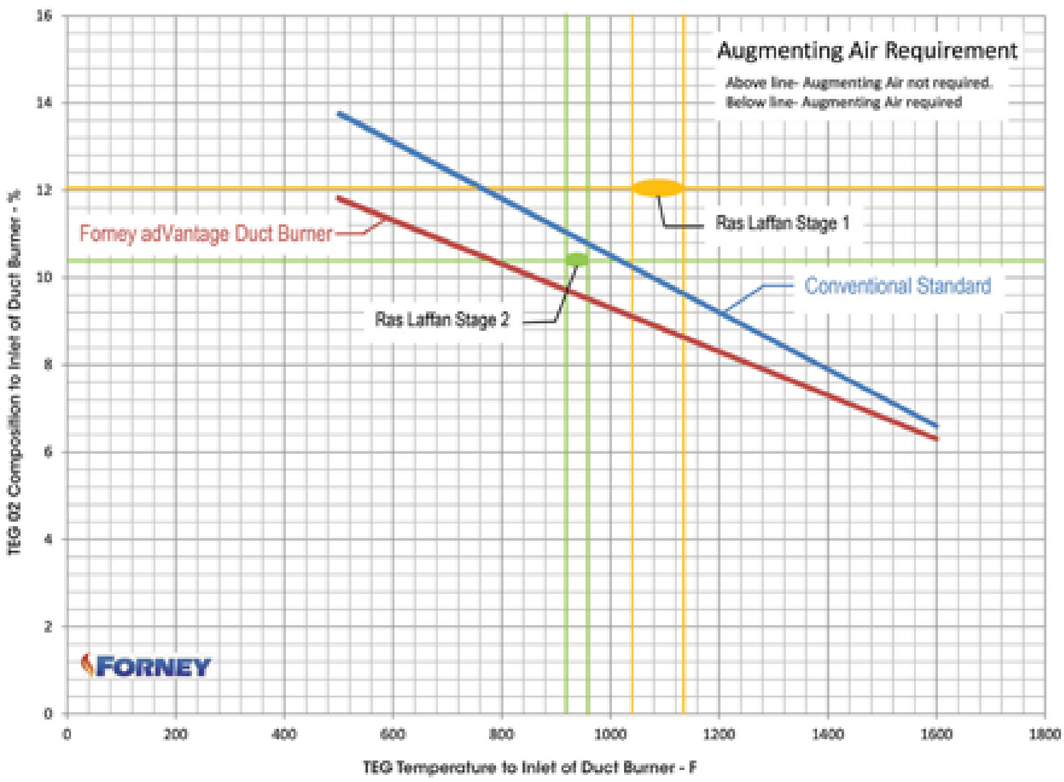
Case study

The emirate of Qatar has emerged as one of the most robust economies within the 21st century Middle East. Qatar has, in recent decades, experienced explosive growth, and with that has come substantial demand for both electricity and potable water. These conditions led to the construction and commissioning of an integrated 1025 MW gas-fired combined-cycle cogeneration power plant and a 273 million litre per day desalination plant in Ras Laffan Industrial City, an industrial hub some 80 km north of Qatar's capital, Doha.

The Ras Laffan Qatar Electricity and Water project was designed by EPC contractor Siemens for high flexibility in operation to address specific operational requirements for production of electrical power or desalinated water. The combined-cycle plant has three Siemens V943A gas turbines, three AC Boilers SpA (formerly Ansaldo Caldaie) HRSGs, and two steam turbines. Steam from the power island is directed to four desalination units that were supplied by Doosan.

The engineering, manufacturing, supply, erection supervision and startup of the three HRSGs was under the project scope of AC Boilers. For this, AC boilers designed the HRSGs to be optimized for varying demand for electricity and water including peaking cycles. During its first year of operation (2006), net production for Ras Laffan was 4,512,250 MWh with 93.2 per cent plant availability.

Based on the demands for maximum steam production over a wide range of gas turbine loads while maximizing cycling capability, two stages of supplemental firing were incorporated into the HRSG design. The two-stage supplemental firing allowed an increase in thermal capacity to meet the variable demand for electric power and desalinated water. This added heat input was provided using duct burners in two stages utilizing Forney's adVantage design.



Typical cooling air blower skid assembly

Credit: Forney

The first stage provides 448 MMBtu/hour, and the second stage provides 544 MMBtu/hour. The first stage supplemental firing utilizes seven duct burners in the HRSG inlet before the superheater. The second stage utilizes eight duct burners installed within the HRSG intermediate section upstream of the evaporator.

The two-stage duct burner arrangement provides distinct advantages over a single-stage design, including optimum temperature profiles.

Based on the GT exhaust gas (TEG) temperature and composition at the inlet of each duct burner stage, as shown in Table 1, Forney determined that augmenting air was not required, avoiding inclusion of augmenting air blower skids in the project scope.

When applying the TEG temperature and O2 content levels to Forney's augmenting air requirements, it is shown in Table 1 (below) that for a conventional duct burner the Stage 1 conditions do not require augmenting air. However, the Stage 2 conditions would require augmenting air for a conventional duct burner. Forney determined that by utilizing the adVantage design which induces turbulence, augmenting air was not required for Stage 2.

Without the use of augmenting air, the plant did not experience any incremental NOx or CO emissions that the additional air would have created. The emissions levels as stated in Table 1 were guaranteed values at the Maximum Continuous Rating (MCR) of the burners and additive to the combustion turbine emissions.

In addition to providing duct burners for the two stages, Forney designed and delivered fuel skid and cooling air blower skid assemblies. These assemblies included valves, instrumentation and controls.

Windy Muehleisen is Project Manager at Forney Corporation. www.forneycorp.com