Proceedings of ASME Turbo Expo 2011
GT2011
June 6-10, 2011, Vancouver, British Columbia, Canada

GT2011-45373

F-CLASS DLN TECHNOLOGY ADVANCEMENTS: DLN2.6+

Krishna Venkataraman
GE Energy
Greenville, SC

Skigh E. Lewis
GE Energy
Greenville, SC

Jayaprakash Natarajan
GE Energy
Greenville, SC

Stephen R. Thomas
GE Energy
Greenville, SC

Joseph V. Citeno
GE Energy
Greenville, SC

ABSTRACT

GE's DLN2.6 system opened the doors to single digit NOx emissions for F-Class industrial gas turbines. Today more than 500 DLN2.6 systems are installed worldwide. GE has recently advanced the technology of F-Class "Dry Low NO_x" (DLN). The new DLN2.6+ technology achieves low-NOx emissions for 9FA and 9FB turbines. Turndown in NOx and CO compliance for 9FB turbines to 32% load and 9FA turbines to 28% load has been demonstrated in the field. This paper will summarize the development history of DLN2.6 and 2.6+ combustion systems and the operating experience of the DLN2.6+. Field validation performance results of the systems will be shared as well as fuel-flexibility results with the DLN2.6+ system.

NOMENCLATURE

HCF – High Cycle Fatigue
HOHC – Higher-Order Hydrocarbons
LCF – Low Cycle Fatigue
MBC – Model-Based Controls
MWI – Modified Wobbe Index

INTRODUCTION

The 9FA and 9FB gas turbines are GE Energy's high-performance air-cooled products for combined-cycle power plants in the 50 Hz segment. The upgrade to the 9FA combustion system, named the DLN2.6+, has significantly improved the operability, emissions, and load turndown range for both 9FA and 9FB combined-cycle platforms. The basic combustion architecture is a multi-can arrangement with 18 identical transition pieces, combustor liners, and combustor head-ends. A new center fuel nozzle and premixer is now added to the head-end arrangement, with controls that serve to stabilize the premixed flame zone over a wide range of conditions and fuel characteristics. As a result, 9FB turbines currently operate with guaranteed NO_x emissions of 50 mg/Nm^3 (24.4 ppm) at 15% O_2, accompanied by guaranteed CO emissions of 12.5 mg/Nm^3 (10 ppm), compliant to these levels down to 38% gas turbine load at ISO-day conditions (with field demonstration down to 32% load). Similarly, 9FA turbines also operate with guaranteed NO_x emissions of 30 mg/Nm^3 (14.6 ppm) at 15% O_2, accompanied by guaranteed CO emissions of 30 mg/Nm^3 (24 ppm); 9FA is also capable of operating with guarantees of 20 mg/Nm^3 (9.8 ppm) NOx at 15% O_2 and 20 mg/Nm^3 (16 ppm) CO. 9FA turbines guarantee turndown to 40% load at ISO-day conditions with extended turndown options below 35% load. For both frames, emissions compliance is assured without the use of aftertreatment.

During development, significant improvements were made in the tolerance to higher hydrocarbon content in the fuel, resulting in an improved fuel nozzle design capable of up to 25% ethane content in the fuel. Application of advanced Model-Based Control (MBC) logic to the system further enhances the capability for tolerance to a wide range of fuel compositions and varying Modified Wobbe Index (MWI) up to 40% (±20%) of design.

There are currently 34 9FB and 28 9FA gas turbines fielded with DLN2.6+ combustors, with several more expected to enter service in 2011. 9FA units are capable of operation up to 24,000 hours between combustion inspections. This capability is based upon extensive DLN2.0+ experience on fielded units as well as rigorous hardware life analyses. 9FB units are capable of operation up to 12,000 hours between combustion inspections.

HISTORICAL PERSPECTIVE AND HERITAGE

GE’s history of development of premixed DLN combustion systems for natural gas fired industrial turbines encompasses two broad classes of combustion architecture. Whereas both classes utilize proven multi-can mechanical arrangements, the differences manifest in the strategies for fuel and air management over the full range of turbine operating conditions. “DLN1” designates axially-staged combustors suitable for the lower range of firing temperatures (E-Class, 2000-2100 ºF) for which the gas turbine cycle provides excess air to the combustor beyond that necessary to maintain low NO_x emissions in premixed flames; the excess air is used for dilution and profile control. “DLN2” designates combustors with multiple radially- or circumferentially-staged, axially parallel flame zones within each can, suitable for the higher range of firing temperatures (F-Class to H-Class, 2300-2500 ºF). As segment pressures intensify for higher performance and lower emissions, the available combustion air must be devoted almost entirely (more than 90%) to premixing with fuel to attain low NO_x emissions. The evolutionary combustion development strategy focuses on optimizing fuel-air mixing and flame stabilization within the design of individual premixers (with greater than 80% mixedness), on fuel allocation to multiple fuel circuits to balance flame stability and emissions, and on cooling of components exposed to ever-higher temperatures.

Figure 1 shows a summary of the DLN2.6+ fleet. The 9FA fleet is broken down into 9FA.01 and 9FA.03 units, which are primarily distinguished by the difference in baseload output. There are a total of 88 DLN2.6+ units operating or underway worldwide.

	9FA.01	9FA.03	9FB
GT Output (MW)	235	260	290
NOx Guarantee (ppm)	15	15	25
Baseload NOx (ppm)	11.5	10	14
CO Guarantee (ppm)	15	24	10
Min Turndown	50%	35%	38%
Field Units	3	25	34
Units Underway	2	8	16

Figure 1. DLN2.6+ Fleet Summary

The DLN2.6+ combustion system derives components and strategies from the evolutionary development of DLN combustors as indicated in Figure 2. GE first commercially introduced DLN1 combustion to industrial gas turbines in 1989 following a long period of development. DLN2.0 was developed to support the higher firing temperatures of F-Class turbines and introduced in 1993; DLN2.0 systems were installed across the GE industrial frame turbine product line[1]. In 1996, the development paths for 60 Hz and 50 Hz products diverged with the introduction of DLN2.6 for the 60 Hz product and DLN2.0+ for the 50 Hz product[2,3]. This divergence recognized a shift in the North American segment toward lower gas turbine exhaust emissions along with application of selective catalytic reduction (SCR) technology to achieve low single-digit power plant NO_x. In the same time frame, the DLN2.5H combustion system was developed to support the steam-cooled H System[*4] Power Island and subsequently a similar DLN2.5H combustion system, although much smaller in size, was developed for the 6C gas turbine.

The DLN2.6 and DLN2.5H systems share a common feature: a patented fuel nozzle arrangement incorporates a center fuel nozzle that ensures a stable flame across a wide range of operating conditions[2]. DLN2.0 systems do not have this feature. The DLN2.0+ and DLN2.5H systems share multiple characteristics in that the fuel-air premixers incorporate the fuel injection gas ports into the swirler vanes, and incorporate swirlers, centerbody and premixing tubes into a fuel nozzle construction called a “swozzle.”[5] The DLN2.0+ also features diffusion gas fuel ports at the swozzle centerbody tips to promote stable ignition and part-speed operation. Advantages of each of these features will be discussed further.

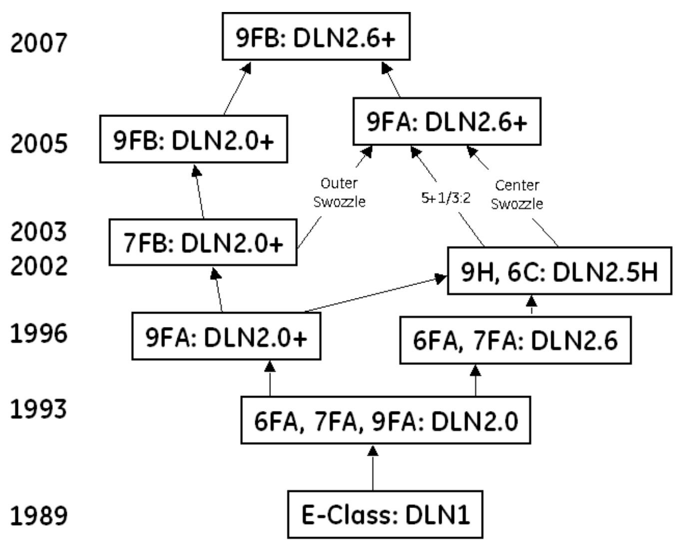

Figure 2. DLN2.6+ Technology Heritage

In 2003 and 2005, the 7FB and 9FB gas turbines, respectively, were introduced, representing an evolutionary step upward in firing temperature from the 7FA and 9FA. The combustor design from the DLN2.0+ was carried forward largely intact, with improvements to air management and cooling to support the higher firing temperature at the same NO_x emission level. As these products neared completion, development of the DLN2.6+ combustion system was initiated to address a growing need for lower NO_x emissions and greater fuel flexibility among the existing fleet of 9FA turbines. By continuously improving upon existing technology, the progression to the DLN2.6+ (outlined in Figure 2) increased firing temperature while decreasing emissions. These improvements also allow the E-Class DLN1 and F-Class DLN2.6 to operate with single-digit NOx emissions, and DLN1+ units are now capable of operation below 5 ppm NOx at 15% O_2.

The DLN2.6+ incorporates the best of strategies developed over the prior evolution: the DLN2.6 center nozzle strategy for flame stabilization and operational flexibility, the DLN2.0+ swozzle design approach for all premixers, and the actual swozzle designs from the DLN2.0+ and 6C DLN2.5H to leverage the large investment in component design and development. The DLN2.6+ was first installed and tested in a 9FA turbine in Italy in late 2005.

Progressive demand for higher performance and lower emissions in the 50 Hz market segment, along with favorable laboratory and field experience with the DLN2.6+, led GE to adopt the DLN2.6+ combustion system for the latest evolution of the 9FB turbine.

SYSTEM DESCRIPTION

The choice of multi-can combustor arrangements enables ease of maintenance and commonality of parts. The proven path of extensive laboratory testing with a single can in a test stand configured to match the turbine flow path, followed by full-scale turbine prototype validation testing, has succeeded over many years in producing highly reliable, cost-effective, and flexible low-emissions combustors. For Frame 9F gas turbines, the arrangement comprises 18 nearly identical cans as illustrated in Figure 3, equally spaced about the turbine centerline. The only can-to-can differences are found in details such as spark plugs, drain valves, and system instrumentation that are not duplicated in every can.

The centerlines of the combustors are canted from the turbine centerline. The combustor flow path dimensions respect the required bulk velocity and residence time considering the cycle airflow rates and temperatures and the specified emissions levels. This step takes into consideration part-load as well as base-load operation, and the emissions-compliant turndown needs of combined-cycle customers. Given these basic dimensions, the flow path is designed to achieve aerodynamically clean flow without flow separation and with uniform velocity profiles entering the turbine stator.

A conical liner inserted into a transition piece defines the hot gas flow path. The transition piece is cooled by impingement and convection, with an impingement sleeve to distribute and control the cooling flow. The liner is cooled by reverse-flow convection in the annulus formed between the liner and flow sleeve.

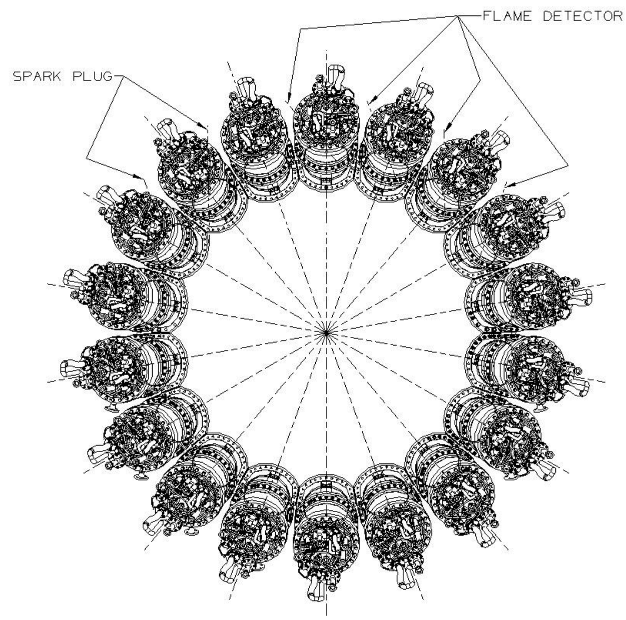

Figure 3. DLN2.6+ Multi-can Layout

Figure 4. DLN2.6+ Head End Arrangement

Figure 4 shows a DLN2.6+ head end arrangement. A cap delimits the forward end of the combustion chamber, the sheet-metal flame face of which is cooled by effusion. Penetrating the cap and flush with the cap flame face are six swozzles, arranged five-around-one as illustrated in Figure 4. The center swozzle is smaller in diameter and in flow area than the five outer swozzles. The endcover that, along with the forward and aft cases, forms the pressure boundary of the combustion system also supports the swozzles. Fuel manifolds embedded in the endcover supply fuel to the swozzles via through-holes connecting the fuel manifolds to the base flanges of the swozzles. Pipes welded to the outer surface of the endcover feed the fuel manifolds. Four connections on each endcover are affixed with quick-disconnect flanges to mate with flexible hoses connecting to the four gas turbine fuel manifolds. Fuel split is the distribution of fuel between the individual fuel circuits, which is controlled to each circuit at the gas turbine level via independent control valves.

Figure 5 is an illustration of the outer swozzle. It has gas fuel ports in the base flange that provide fuel to diffusion ports at the tip of the centerbody and to cavities in the swirl vanes, and thereby to gas discharge ports in the airfoil surfaces of the vanes. The gas fuel mixes with air as the air is turned through the vane turning section, and continues to mix through the mixing annulus downstream of the swirl vanes before the end of the centerbody. The outer swozzle is identical to designs used in DLN2.0+ combustors, and differs only in the arrangement and sizing of premix and diffusion gas ports.

Figure 5. Outer Swozzle

The outer swozzle illustrated in Figure 5 is capable of operation in dual-fuel configuration, in which liquid fuel can be injected through a removable center cartridge into a diffusion flame. Low emissions are achieved in liquid-fuel operation by injection of water as a flame diluent; the liquid cartridge also supplies atomizing air from an off-base compressor to assist with ignition and low-power operation. For gas-only configurations, the center cartridge is replaced with a purged “blank” cartridge.

The center swozzle, which is very similar in structure to the outer swozzle, has only one premix fuel passage and no diffusion fuel or center cartridge.

OPERATIONAL STRATEGY

The DLN2.6+ operation is based upon a patented asymmetric fueling strategy. The operational modes are described in terms of which fuel and diluent injection circuits are active. There are four gas fuel circuits (named D5, PM1, PM2 and PM3), one liquid fuel (LF) circuit, and a water injection (W) circuit. Figure 6 illustrates the gas fuel management strategy. The center swozzle is fueled by the PM1 circuit, two non-adjacent outer swozzles are fueled by the PM2 circuit, and the remaining three outer swozzles are fueled by PM3. “PM” refers to premix fuel. The D5 circuit provides diffusion gas fuel to the five outer swozzles. LF and W circuits (not shown) provide their respective fluids to the cartridges in the five outer swozzles.

During ignition, fuel flows to all 18 cans. Spark plugs fire in two of the 18 cans and the remaining are ignited via cross-fire tubes. Light around is detected by flame detectors; successful light around is also observed by exhaust temperature spread monitoring using an array of thermocouples located in the turbine exhaust duct. Ignition occurs in diffusion mode with the five outer nozzles fueled in each chamber. During acceleration, premix fuel is initiated to the center fuel nozzle.

There are actually four possible modes of operation at base load, including a primary and backup path with gas fuel, and liquid fuel with and without water injection. The primary gas-fuel path is compliant to emissions guarantees, whereas the backup path permits continued operation out of emissions compliance in the event of a subsystem fault. Operation with liquid fuel is only compliant to emissions guarantees when water injection is active.

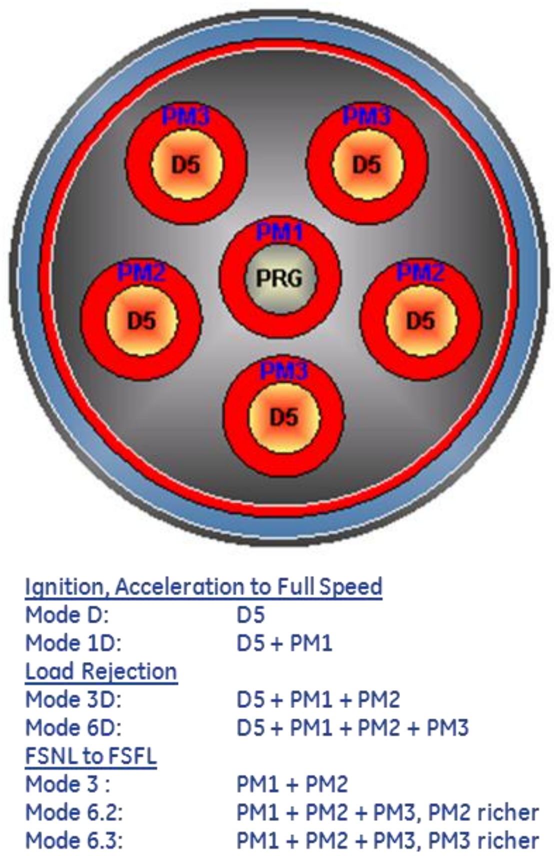

Figure 6. Gas Fuel Management Strategy

Stability over the steady operating range of each mode is assured by controlling the fuel to each circuit in an uneven fashion, causing certain nozzles to be richer than others. This strategy has been proven to reduce pressure instabilities and provides margin to lean blowout without excessive NO_x emissions. The center swozzle is used throughout premix operation as a flame anchor. Extensive laboratory development proved that this strategy provided low emissions and pressure fluctuations, as well as low sensitivity to fuel composition variations.

The backup path assures a stable flame by keeping diffusion fuel on throughout the load range. Otherwise, the modes are similar to the primary path modes. For any modes that leave a fuel circuit inactive, the unused fuel circuits are purged to prevent quiescent volumes from accumulating condensation. Transfer between primary and backup path is possible at any load.

Transient modes are implemented for breaker-open events (loss of load), where enrichment of PM1 prevents lean blowout. Islanding operation is possible to loads up to 40 MW for 9FA and up to 25 MW for 9FB. To attain low NO_x emissions at part load, the primary path maintains premixed operation from breaker closure to full load. To attain low NO_x emissions at the elevated 9FB firing temperature, airflow was managed to present greater than 90% of the total air available to the combustion system into the primary flame zone. This required great attention to sealing and cooling secondary flows. During low-emissions, premix operation, typical combustion dynamics are 25% below recommended limits due to advancements in proprietary and patented fuel nozzle technology.

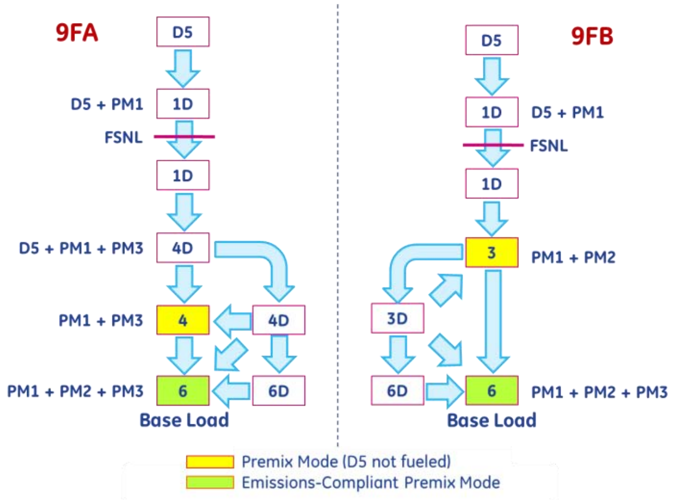

Figure 7. DLN2.6+ fuel mode sequences

Figure 7 shows the fuel mode sequences for the DLN2.6+ combustors. This figure highlights the differences between the operation of the 9FA and the 9FB. The 9FA's use the diffusion circuit more during part-load operation and therefore have higher NOx and lower CO emissions during part-load than the 9FB. The 9FB is able to operate to a higher firing temperature and is thus able to schedule the fuel circuits closer to an even fuel split, which allows operation closer to the minimum emissions level.

DESIGN CONSIDERATIONS

NO_x emissions are the most significant consideration in designing fuel-air premixers; however the design must balance low emissions and flame stability. Having selected the basic head-end arrangement, the design team proceeded to survey the available existing designs of swozzles to select designs for the DLN2.6+ design targets. The DLN2.0+ swozzle was well characterized and an obvious choice for the outer swozzle. The center position demanded a smaller center nozzle due to space constraints.

Despite the smaller-size center nozzle, the arrangement of 5 DLN2.0+ swozzles around the center nozzle dictates a larger cap outer diameter than the original DLN2.0+ design. The larger diameter results in a larger overall combustor volume and lower head-end bulk velocity, which is advantaged for turndown. These design changes are fully retrofitable on DLN2.0+ combustion systems, providing the opportunity for existing DLN2.0+ sites to upgrade to the DLN2.6+ combustion system.

Design analysts employed 3-D Computer-Aided Engineering (CAE) tools to estimate thermal and structural loading and responses of all components, and thereby predict component life with respect to major failure modes (HCF, LCF, creep, and oxidation). For the 9FB application a mission-based analysis approach completed life predictions for eight different operating conditions over the range from no load to full load, focusing on conditions that create a non-uniform thermal load on components as well as those conditions that create the highest thermal loads.

LABORATORY DEVELOPMENT

One of the key lessons learned throughout the development of the DLN systems is the importance of testing. More than 1600 hours of lab testing, during more than 400 development tests, were completed during development of the DLN2.6+ combustion system. These tests included a wide variety of fuel blends and operating modes while continuously improving the system.

GE executes its full-scale laboratory testing for industrial gas turbine combustors at the Gas Turbine Technical Laboratory (GTTL) facility located in Greenville, South Carolina. GTTL is capable of testing industrial gas turbine combustors including the 9FA and 9FB at full-scale, full-flow conditions including variations in fuel composition over the full range of interest, on a single-can basis.

The full-scale test stand for the DLN2.6+ combustor simulates a 1/18 sector of the gas turbine mid frame, with sidewalls representing the symmetry plane between cans. The GTTL facility is capable of measuring dynamics amplitudes and frequencies up to approximately 6400 Hz. Dynamic pressure fluctuations are common in lean premixed, swirl-stabilized flames in acoustic enclosures. Frequencies vary depending on a number of conditions including ambient temperature, load, and fueling mode among others.

During testing and development, instrumentation is commonly applied to hardware that enables measurements of surface and air temperatures, total and static pressures, and emissions. The facility is capable of performing full-scale cold flow and fired tests as well as individual component tests. These tests aid in determining operability boundaries during development, namely lean blowout, dynamics, emissions, and hardware durability. Figure 8 shows a 9F transition piece with pressure and temperature instrumentation and a thermal paint coating to indicate metal temperature contours during full-scale operation. For each lab test performed, data are stored in a secure database that allows access to current and historic test results, enabling design engineers to query and analyze years of data under a broad range of conditions.

Figure 8. 9F transition piece with thermal paint

FIELD VALIDATION AND DEMONSTRATION

Three DLN2.6+ launch sites have been tested extensively with instrumented combustors to fully characterize the performance, emissions, and component durability. The first site was a 9FA turbine, whereas the second and third sites were 9FB turbines. Additional sites have been commissioned without instrumented tests. The following discussion focuses on field data from the 9FB sites.

In order to validate the aerothermal and mechanical performance of the combustion system, multiple combustor cans are extensively instrumented. A suite of more than 400 applied instruments such as thermocouples, pressure probes, strain gages and accelerometers were utilized. The measured temperatures and pressure distribution at a wide range of GT operating conditions (load, combustor modes and ambient conditions etc.,) are analyzed to accurately predict the durability of the combustor components and combustor airflow distribution.

Moreover, field-testing provides an opportunity to characterize the combustion system behavior with respect to the controls effectors and to define control schedules to best balance the requirements. Fuel distribution is the main combustion control effector, referenced as split fractions of fuel to each circuit on a remainder (percentage) basis. Thus, where:

W_{D5} = fuel flow to D5 circuit
W_{PM1} = fuel flow to PM1 circuit
W_{PM2} = fuel flow to PM2 circuit
W_{PM3} = fuel flow to PM3 circuit
and W_{fuel} = total fuel flow,

remainder fuel splits are defined as:

D5% = % of total fuel to D5 circuit = $W_{D5}/W_{fuel} * 100$
PM1% = % of premix fuel to PM1
$= W_{PM1}/(W_{fuel}-W_{D5}) * 100$
PM3% = % of remainder fuel to PM3
$= W_{PM3}/(W_{PM2}+W_{PM3}) * 100$

The control system calculates fuel splits continuously with closed-loop comparison to predefined schedules; hence the schedules must assure that the emissions requirements are met, and that thermal and dynamic pressure loadings on components are within acceptable ranges. In addition, anticipated variations in ambient conditions and in fuel characteristics must not drive any of these criteria outside of acceptable bounds.

Variation in fuel composition manifests primarily in density and heat content, described by the MWI[5], defined as

$$MWI = \frac{LHV}{\sqrt{SG*T}}$$

where LHV is the gas lower heating value (volumetric basis), SG is the gas specific gravity, and T is the gas absolute temperature. For a given firing temperature, nozzle pressure ratios change in direct proportion to MWI. These changes result in a deviation from the optimum nozzle pressure ratio for dynamic pressures and emissions. Additional capability exists to operate with a wider MWI range by varying fuel splits in response to changes in MWI.

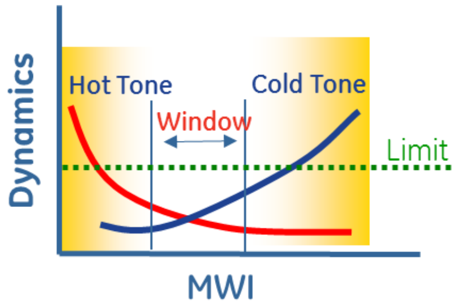

Figure 9. Typical combustion dynamics behavior with respect to changing MWI

Figure 9 shows the general combustion dynamics trend with respect to changing MWI. All DLN2.6+ nozzles are designed to be capable of ±5% deviation of the design MWI. As the MWI changes, the nozzle pressure ratio changes, which directly impacts combustion dynamics. Figure 10 shows test results using a set of 9FA fuel nozzles illustrating the nozzle MWI capability. The figure reveals that the 9FA combustion systems are capable of greater than ±10% MWI without changes to fuel splits. Fuel splits can also be adjusted to further enhance MWI capability. Those fuel splits are adjusted using independent control valves for the PM1, PM2, and PM3 circuits. MWI can be calculated online using a gas chromatograph and fuel temperature.

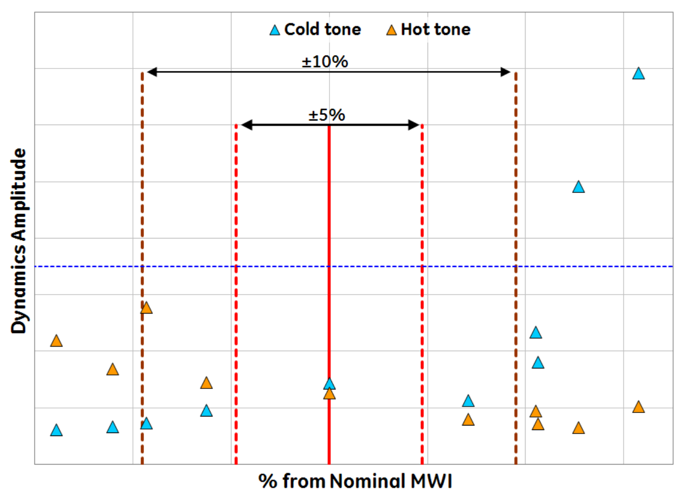

Figure 10. 9FA data showing dynamics vs. MWI

Figure 11 and Figure 12 are representative plots of DLN2.6+ cold and hot combustion dynamics tones, respectively, versus nozzle pressure ratio. These figures illustrate that data taken during laboratory testing compares very well to field data. This is also true with field versus lab emissions as well as other critical data. Results obtained during lab testing and development are characteristic of data obtained during field tests.

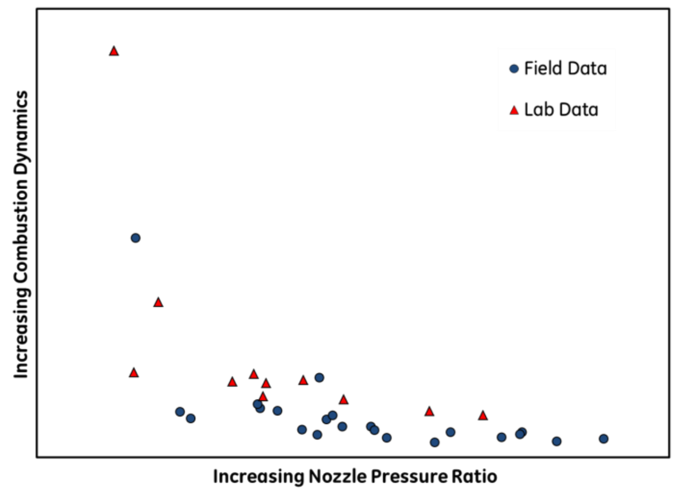

Figure 11. DLN2.6+ field vs. lab cold tone dynamics

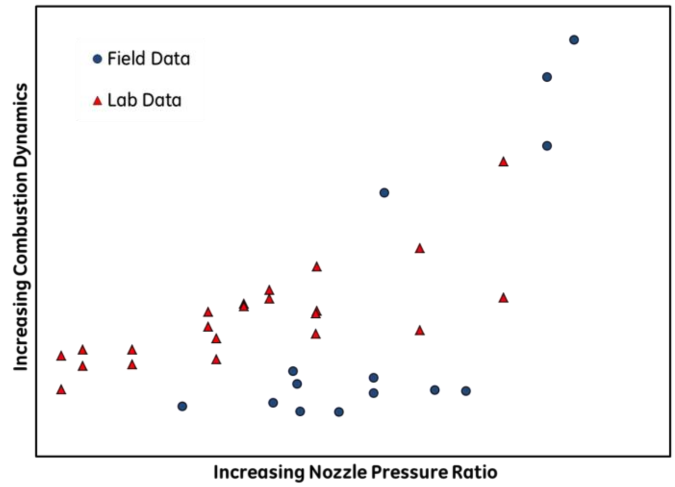

Figure 12. DLN2.6+ field vs. lab hot tone dynamics

Chosen fuel splits for base load operation reflect margin to the NO_x emission limit, dynamics limit and component durability limit as well as margin for fuel variation. Figure 13 shows boundaries of these observed limits during a 9FB field test at base load operating conditions. It should be noted here that the indicated PM1 and PM3 splits are referenced from the target PM1/PM3 split. As indicated in Figure 13, there is significant margin on PM1 and PM3 split to emissions, dynamics and durability boundaries from the target-split condition.

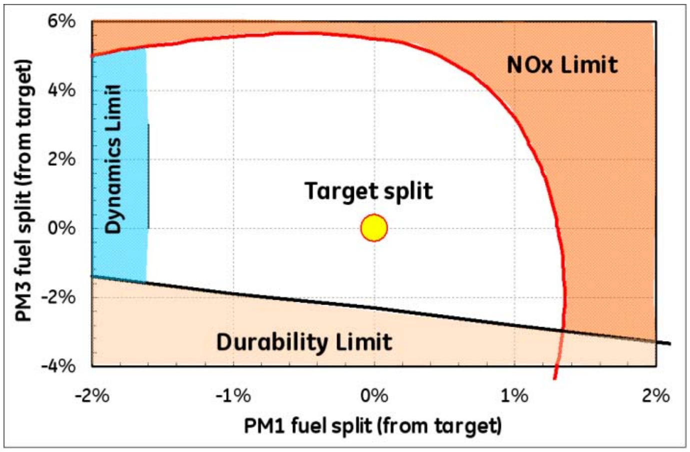

Figure 13. Operability window at base load conditions

Similarly the target splits at various loading conditions are tuned as a trade-off between emissions, dynamics, durability and lean blowout margin. The schedules are tuned to maintain constant NO_x with an offset from the guarantee (50 mg/Nm^3) intended to allow for changes in ambient or fuel conditions. Figure 14 shows the field-measured emissions data during operation at various GT loading conditions. This indicates that compliance to the guaranteed NOx and CO emissions level is assured above the current guarantee level of 38% load. The NOx is relatively constant at all loading conditions, while the CO picks up below 40% load and reaches the 12.5 mg/ Nm^3 (10 ppm) guarantee limit at about ~32% load. Even below the emissions compliant range, the NO_x levels are relatively low, owing to the fully premixed operation.

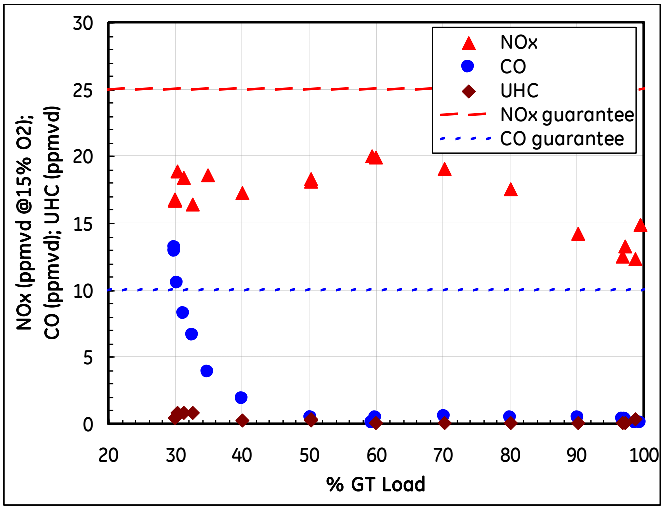

Figure 14. Variations of measured NOx, CO and UHC emissions with %GT load from a 9FB site

CONCLUSIONS

Successful product introduction and field validation of the DLN2.6+ combustion system for Frame 9F turbines represent a significant step in emissions performance and operational flexibility. NO_x emissions can now be guaranteed at 30 mg/Nm^3 in 9FA and 9FB turbines for the first time, with optional higher ratings for 9FB at 40 and 50 mg/Nm^3. At the same time, load turndown with emissions compliance can be guaranteed to below 40% gas turbine load at ISO conditions.

ACKNOWLEDGMENTS

The authors would like to acknowledge the work of combustion engineers Brad Crawley, Michael Hughes, Gregory Jensen, Mark Pinson, and Stan Widener, whose efforts were instrumental in the successful development and fielding of the DLN2.6+ combustion system.

REFERENCES

1. Davis, L. Berkley, and Black, Steven. (2000) "Dry Low NOx Combustion Systems for GE Heavy-Duty Gas Turbines", GE Publication GER-3568G.
2. Vandervort, Christian L. (2000). 9 ppm NOx / CO Combustion System for "F" Class Industrial Gas Turbines. ASME Paper No. 2000-GT-0086.
3. Myers, Geoff et. al. "Field Test Validation of the DLN2.5H Combustion System on the 9H Gas Turbine at Baglan Bay Power Station", ASME Turbo Expo 2005, GT2005-68843, June 2005, Reno, Nevada.
4. Tuthill et. al., "Swozzle Based Burner Tube Premixer Including Inlet Air Conditioner for Low Emissions Combustion," US Patent 6,438,961, 2002.
5. Tiratsoo, E. N., "Natural Gas," Scientific Press Ltd., Beaconsfield, England, 1972.