Prediction of Lean Blowout in a Gas Turbine Engine

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Overview

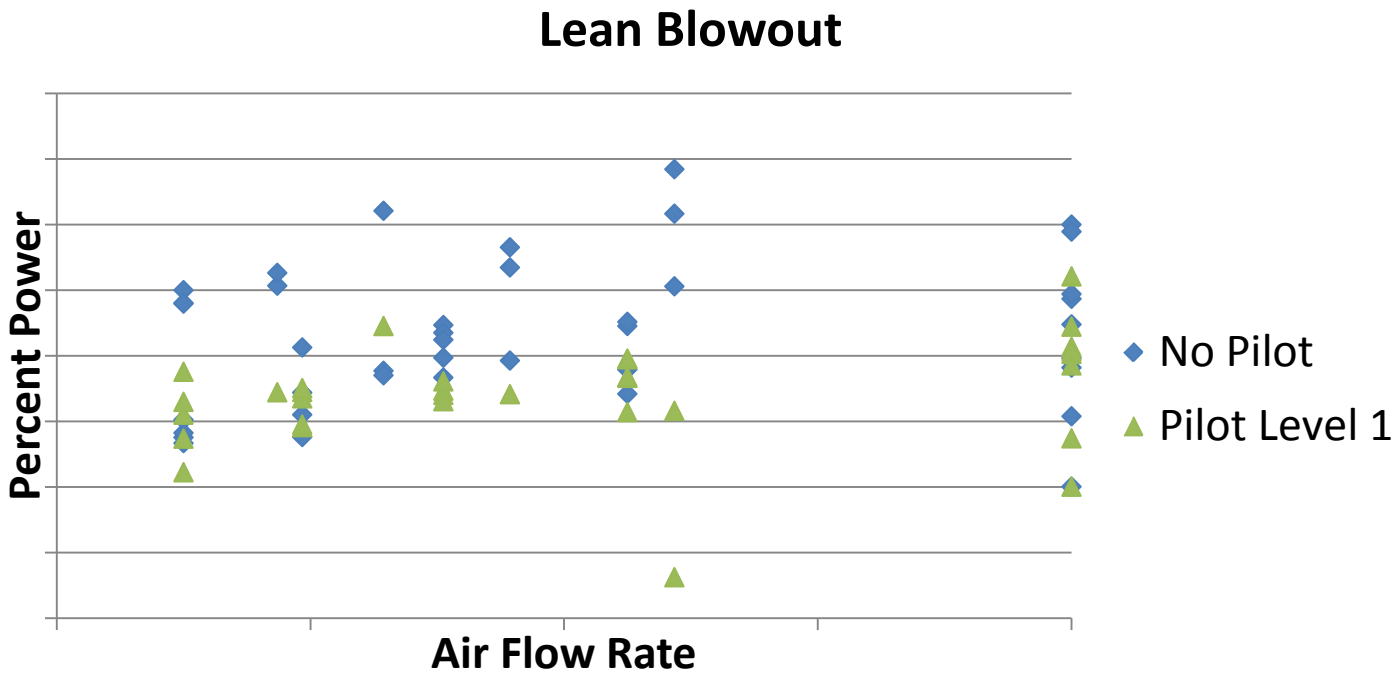
- FlexEnergy manufactures gas turbines operating in the 250kW power range
- The lean-premixed combustion regime they operate in is susceptible to extinction via blowout
  - Pilots stabilize combustion, but introduce diffusion flames, which increase emissions
  - Pilots are turned on in two levels to allow a greater operating range with a reduced emissions impact
- Updated engine adds features that improve stability characteristics
  - Need to determine operating envelope and pilot schedule

Test Procedure

1. Set inlet air flow rate
2. Set power to achieve proper operating temperature
3. Allow turbine to reach steady state conditions
4. Manually set pilot valves
5. Reduce output power, and therefore fuel flow

- Data collected during ramp and blowout
- Data also collected at steady state conditions
- Repeated for multiple air flow rates, fuels, combustors
- Only no pilot and pilot level 1 tested

Results



- Pilot level 1 extends operating range, as expected
- The data is spread out
  - Percent power does not predict blowout precisely

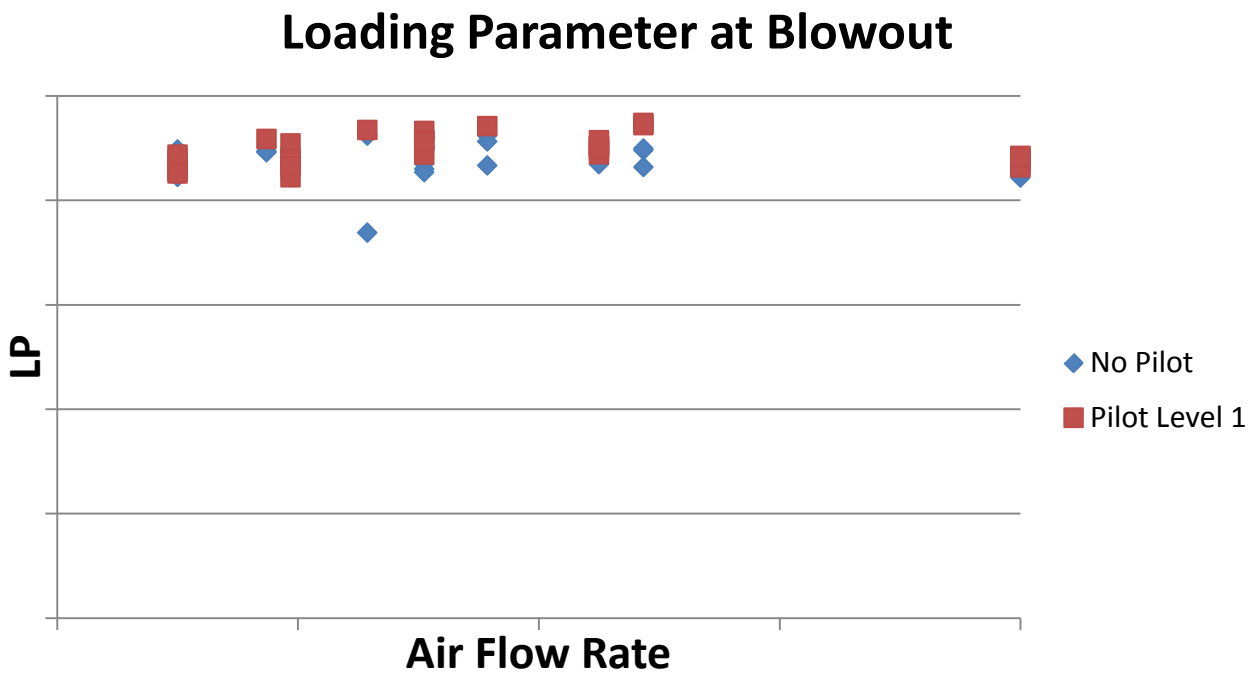
Combustor Loading Parameter

- $LP = \frac{\dot{m}_{air}}{V * P^n}$
  - Reaction volume, V, is unknown but constant

- Serves as a predictor of blowout

- Stable combustion ↔ low LP
- Unstable combustion, Blowout ↔ high LP

Combustor Loading Parameter



- Data is significantly less spread out
  - Blowout can be accurately predicted
- Very little difference between pilot level 1 and no pilot blowout
  - Difficult to stage pilot schedule

Transient Analysis

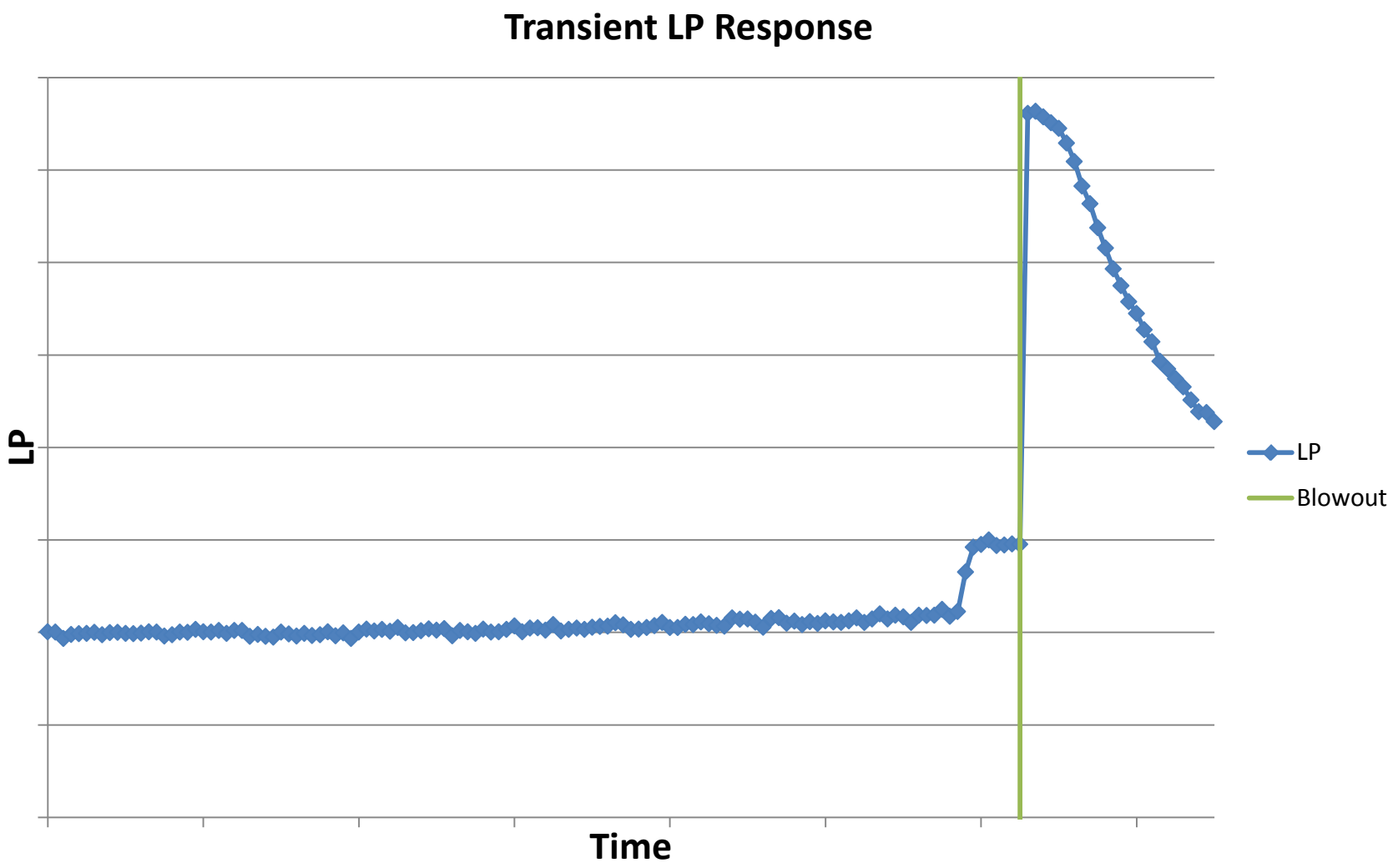
No Pilot:

- Consistently saw a sharp increase (step change) in LP shortly before blowout
- Magnitude outweighed variation in steady state data significantly

Pilot Level 1:

- Much less consistent response than no pilot
- Likely due to introduction of diffusion flame and moving away from well-mixed combustion, where LP is well defined

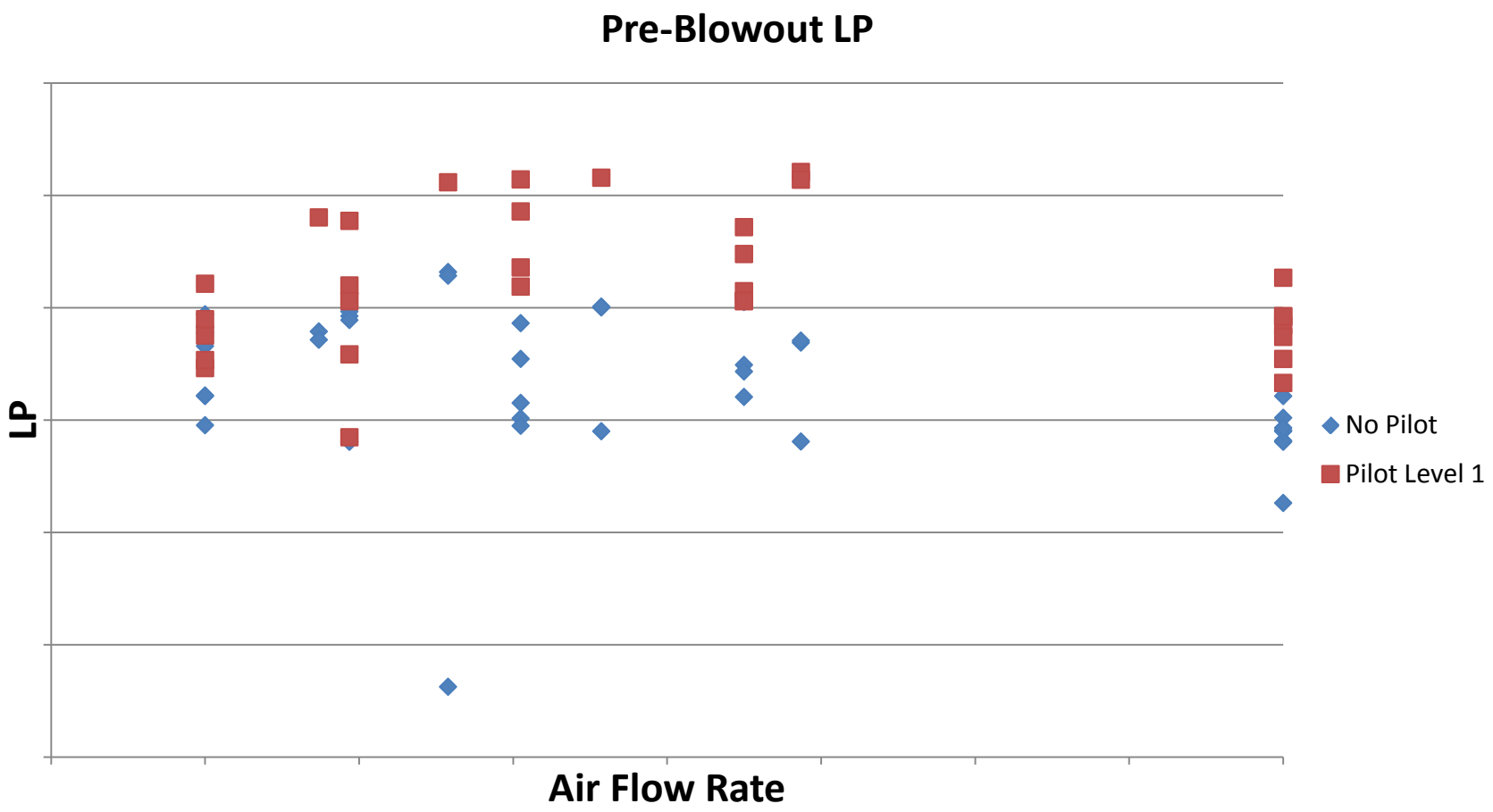
No Pilot Transient Response



LP Values Before Blowout

- Saw from transient responses that LP increases at or immediately before blowout
- Investigate LP values *before* blowout, since this is when we would like to adjust pilots
- Greater increase in LP for no pilot data at blowout
  - Looking at pre-blowout LP separates the no pilot data from the pilot level 1 data

LP Values Before Blowout



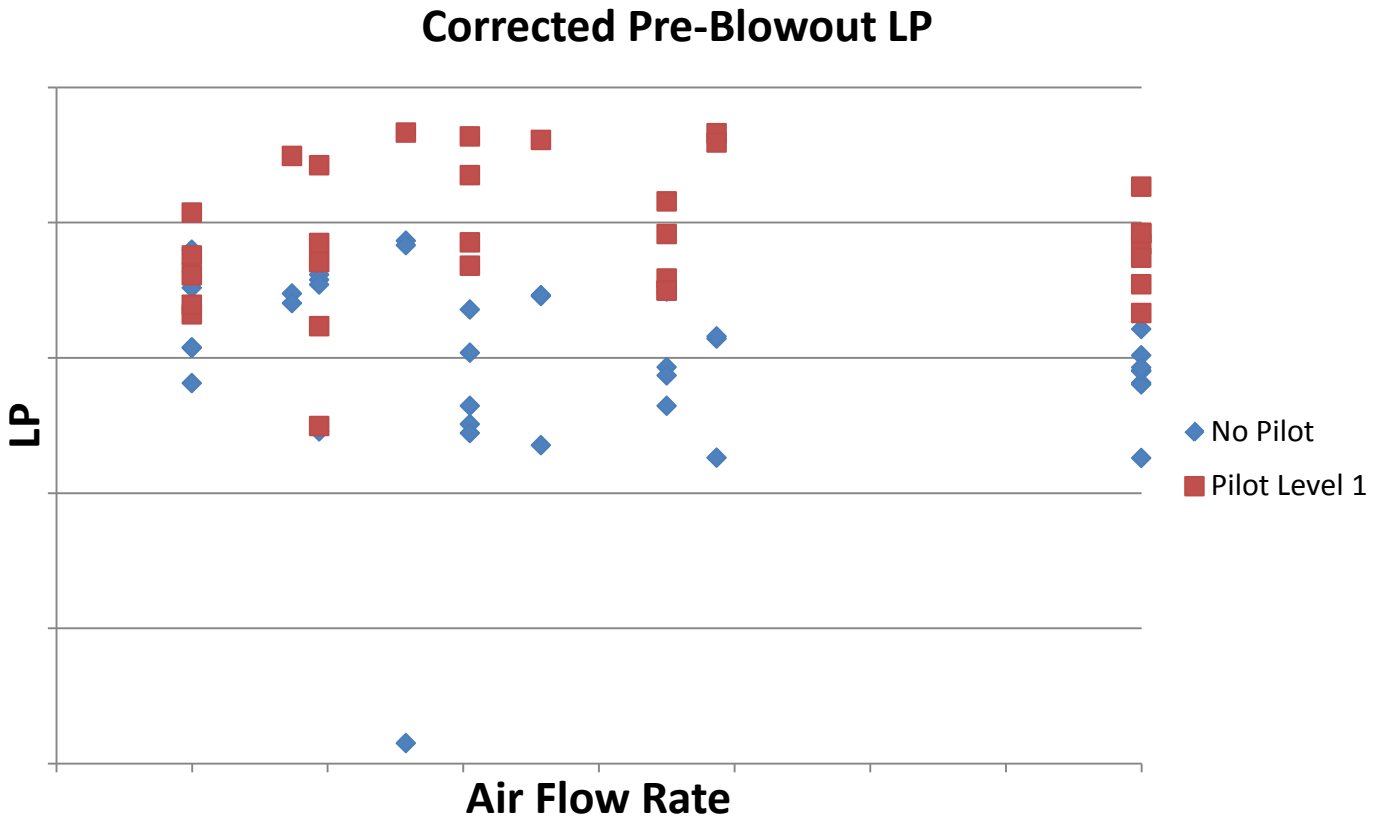
Vertical range has been reduced to show variations in data

LP Values Before Blowout

- Spread is roughly the same as for data at blowout
- More separation between no pilot and pilot level 1 data

- Data shows slight trends with other combustor related variables (e.g. temperature)
  - Removing these trends provides a more complete description of blowout

LP Values Before Blowout



The corrections:

- Decrease data spread
- Further separate no pilot from pilot level 1 blowout

Conclusions

- Validate that pilot level 1 effectively increases turbine operating envelope
- LP with slight modifications successfully predicts blowout conditions
- Can use LP to create staged pilot schedule to prevent blowout while minimizing harmful emissions

Future Work

- Pilot schedule must be implemented and tested to validate effectiveness

- Analysis found minimal differences across combustors and fuels tested
  - Suggests that LP at blowout may be constant across all combustors and fuels used
  - More testing needed to confirm

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