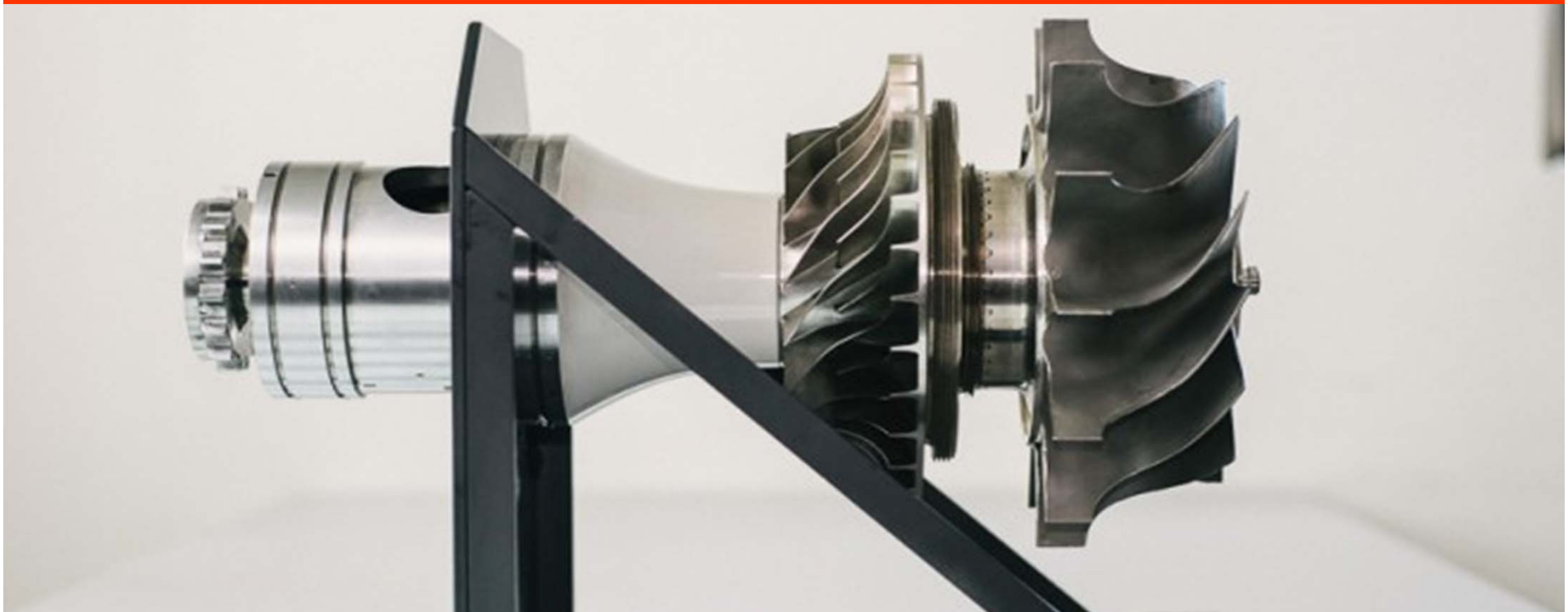
Testing Off-Grid Operations on Digester (Low Btu) Fuels



UTSR Fellow: Andrew Bakir, University of Colorado

Industrial Mentor: Jeffrey Armstrong, FlexEnergy Inc.

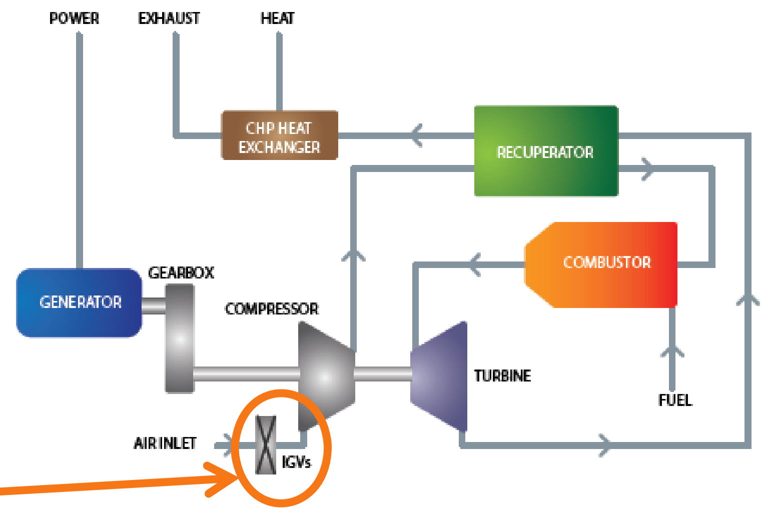
June – August 2015

Purpose

The main priority for the summer was qualifying the GT333S on low caloric value fuels (500-800 Btu/scf) by testing four areas*:

- Ignition
- **Off-Grid Load Following** (topic of this presentation)
- Fuel Following
- Emissions

GT333S GAS TURBINE CYCLE



New key feature: Inlet guide vanes improve part-load conditions

*Sensitive information was removed from the following presentation due to proprietary rights.

Presentation Overview

- Concepts
- Testing / Data Collection
- Off-Grid Load Following
  - Test 1 – Triple Pump-Jack Operations
  - Test 2 – Simulating Abrupt Power Demands
- Conclusion

Concepts

- Combustion
  - Minimum ignition energy
  - Air – fuel ratio
  - Flame stability
  - Rate of fuel flow and fuel supply pressure
- Modeling power cycles
  - Energy analysis
    - Conservation of Energy!
  - Brayton cycle <u>with</u> regeneration

<u>Steady State</u>

$$\dot{E}_{in} = \dot{E}_{out}$$

Testing and Data Collection

Tests conducted on R&D GT333S at FlexEnergy's Portsmouth production facility.

FUEL: Mixed natural gas and CO_2 to deliver desired heating value to engine.

DATA: Unit's monitoring system recorded engine parameters to an automated analysis log.

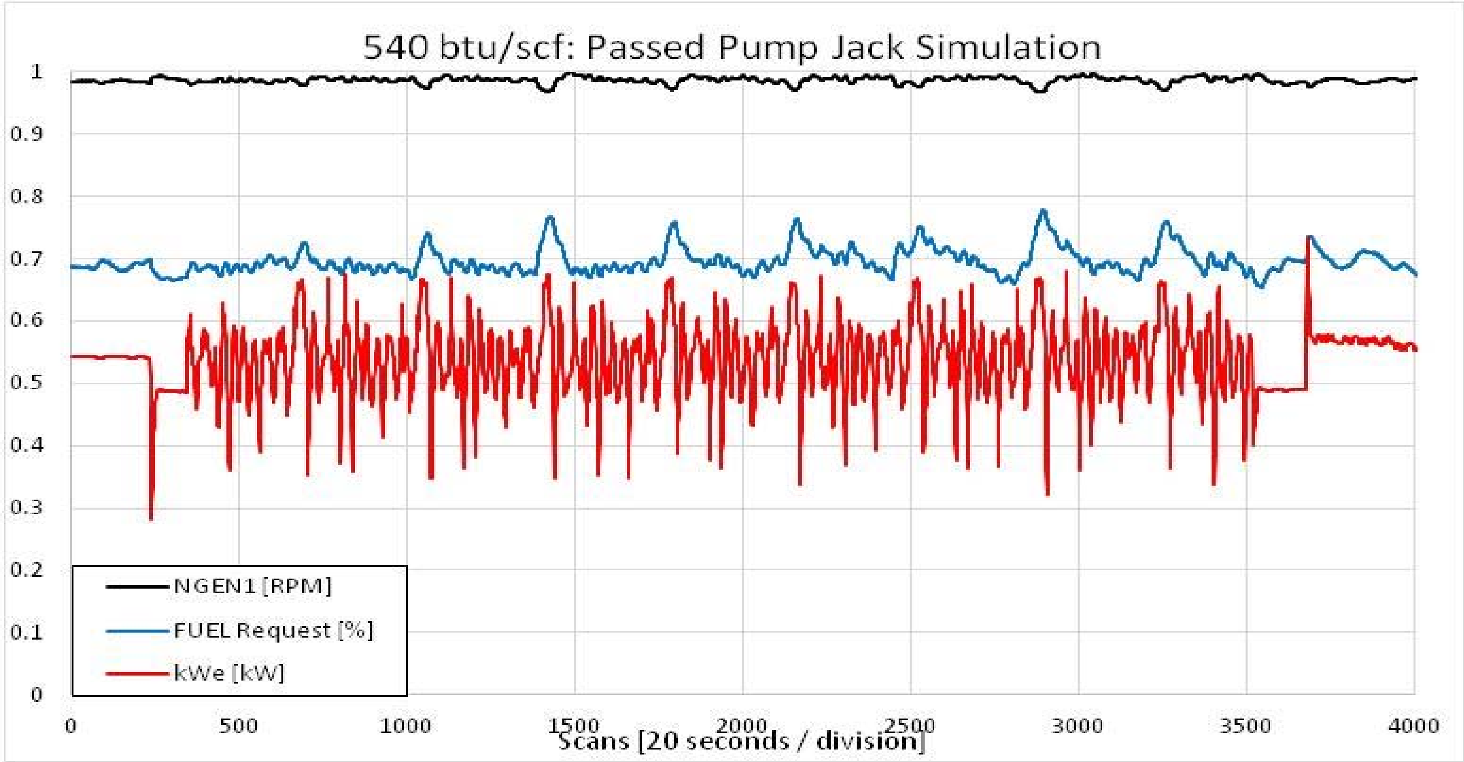
Criteria: Tests were considered successful if operating limits were within limits and no faults were tripped.

Test 1 – Triple Pump-Jack Simulation

Two minute cycles were applied to test the engine's performance throughout the Btu range of interest.

Test 1 – Triple Pump-Jack Simulation

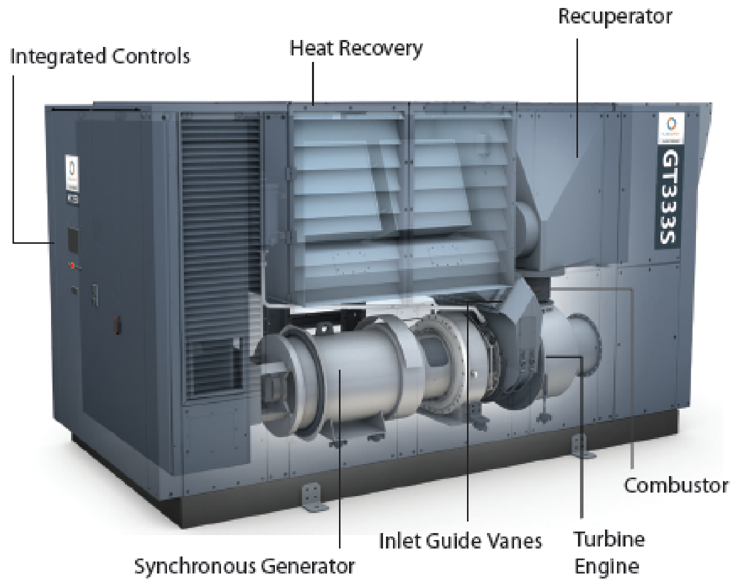
The example below shows the load cycle denoted by kWe. Here you can see the engine was able to keep the speed (NGEN1) relatively constant by adjusting the fuel input (Fuel Request).



Test 2 – Applied Load Steps

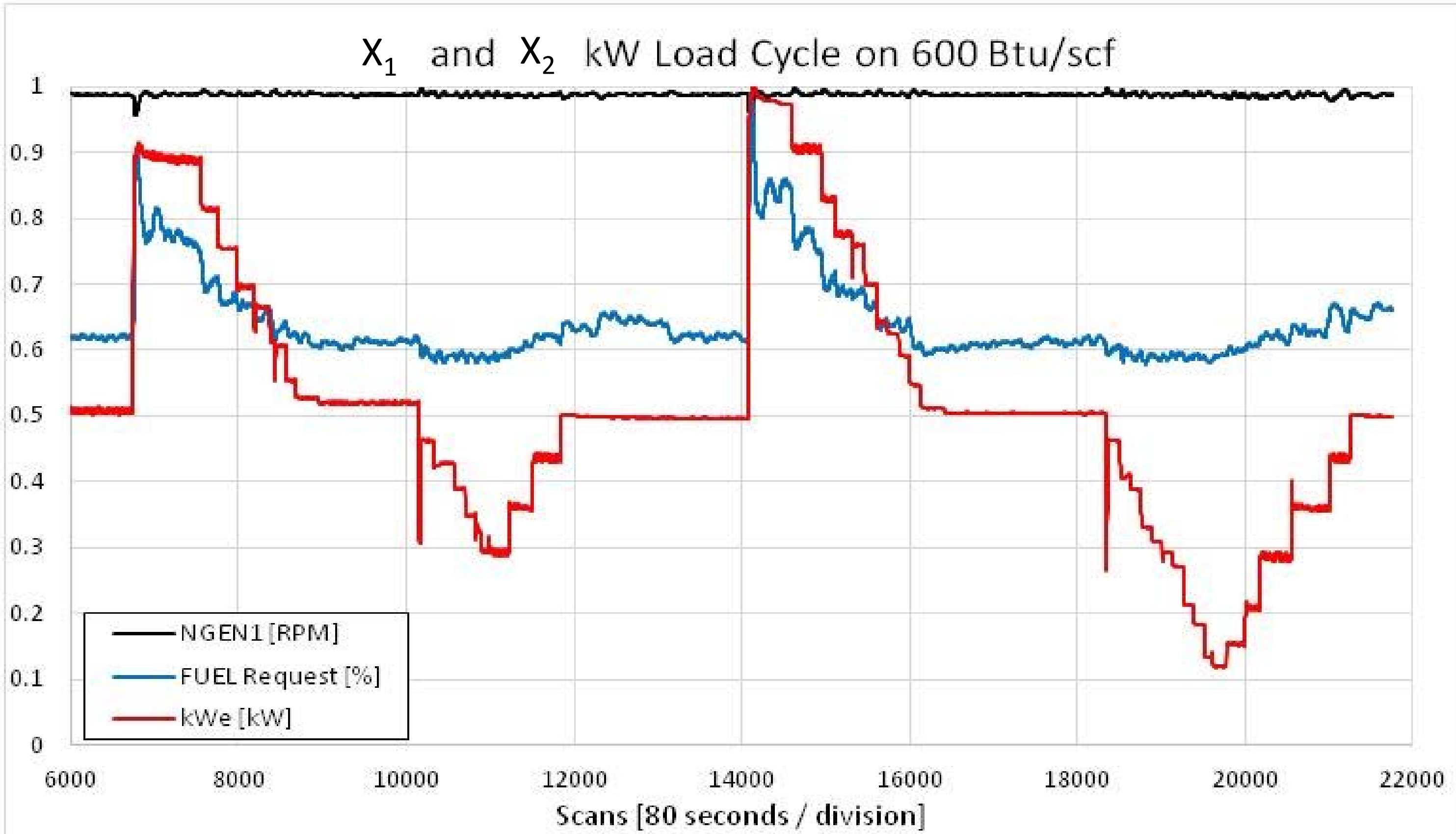
The following test ensured:

1. Turbine generator can supply demanded power
2. The generator braking resistor (GBR) is able to absorb the power off loaded by the engine
3. Minimum power setting for continuous engine operation without triggering faults.



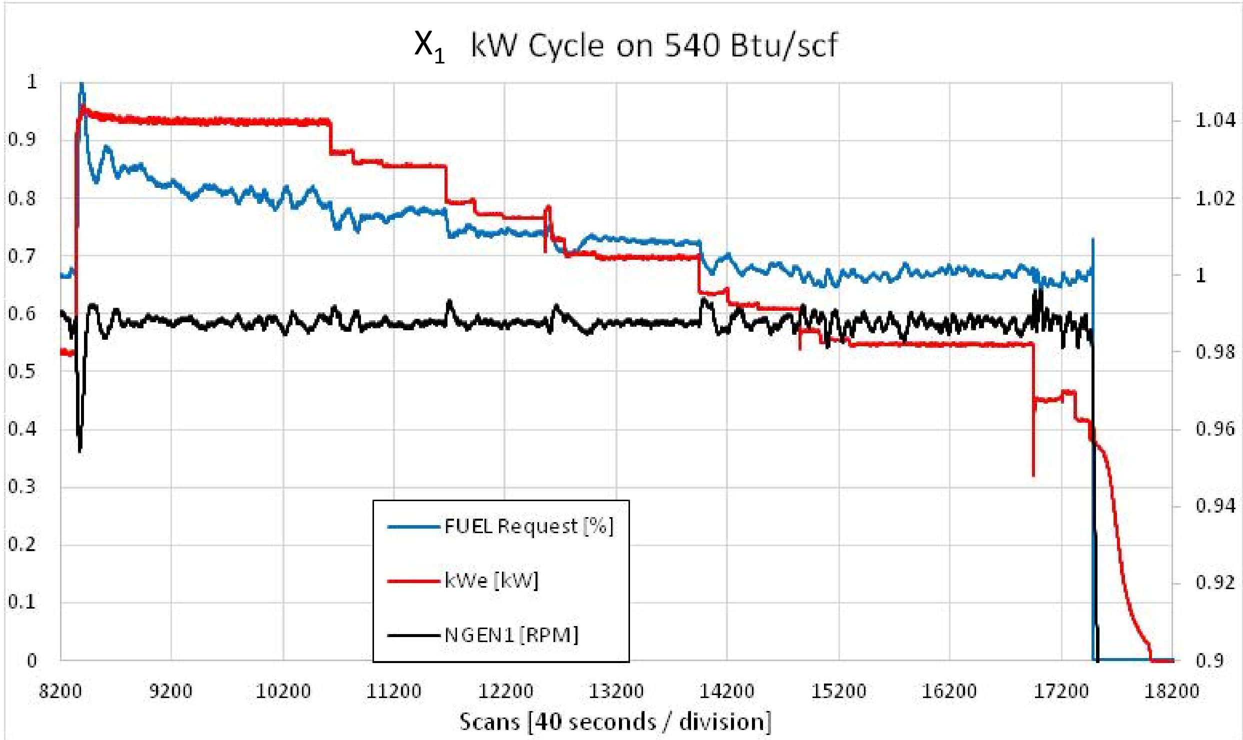
Test 2 – Fuel heating value of 600 Btu/scf

Natural gas was diluted to 67% the mean heating value for this test and the engine operated steady with no faults.



Test 2 – Fuel heating value of 540 Btu/scf

Further fuel dilution, the engine was unable to operate when the load demand was too low.



Test 2 – Fuel heating value of 540 Btu/scf

The test on 60% diluted natural gas provided valuable results to improve the engine control and monitoring system. At the conclusion of the fellowship, further testing was needed to verify the recommended minimum power settings.

Conclusion

Test 1

GT333S can successfully handle three pump-jack loads in the desired Btu range. Important to note, the engine speed stayed relatively constant, varying less than 1.5% from the design speed.

Test 2

GT333S can provide the necessary loads for off-grid operations running on digester gas. A recommended minimum power setting requires further testing.

Acknowledgements

I would like to thank the entire **FlexEnergy team** for their support and professionalism to create an exceptional workplace. The patience demonstrated by team members who were readily available to assist me was not overlooked. In particular I would like to thank **Jeff Armstrong** for his advice and guidance throughout the fellowship. **Tom Hackett**, **Dr. Chris Bolin**, **Adam Mitchneck**, and **Dr. Mohammed Ebrahim** for their assistance on testing and sharing their knowledge with me.

I also wish to thank the **Southwest Research Institute** for selecting me into the UTSR fellowship program. I have learned a great deal about gas turbines and combustion from this opportunity and I am indebted to take away a wealth of knowledge.

UTSR
University Turbine Systems Research

DEPARTMENT OF ENERGY
UNITED STATES OF AMERICA