Federal Aviation
Administration

Development of the Next Generation Fire Test Burner for Powerplant Fire Testing Applications

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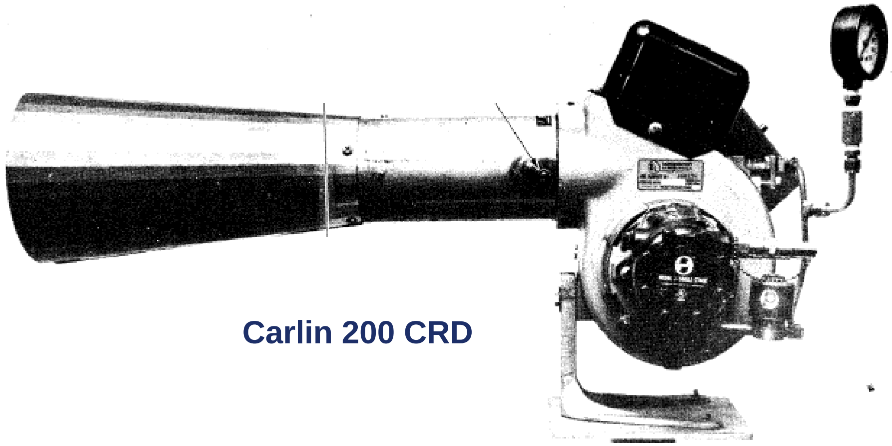
Powerplant Fire Testing - FAA Regulatory Information

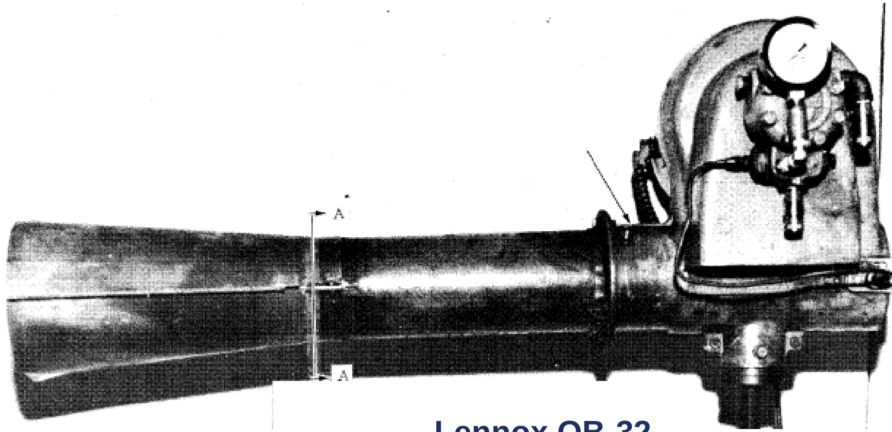
- **Numerous FAR's mandate fire protection in aircraft powerplant fire zones**
  - Parts 23, 25, 27, 29, 33…
  - FAR Part 1 Section 1.1 – Definitions and Abbreviations
    - Fireproof--
      - (1) With respect to materials and parts used to confine fire in a designated fire zone, means the capacity to withstand at least as well as steel in dimensions appropriate for the purpose for which they are used, the heat produced when there is a severe fire of extended duration in that zone;
      - (2) With respect to other materials and parts, means the capacity to withstand the heat associated with fire at least as well as steel in dimensions appropriate for the purpose for which they are used.
    - Fire resistant--
      - (1) With respect to sheet or structural members means the capacity to withstand the heat associated with fire at least as well as aluminum alloy in dimensions appropriate for the purpose for which they are used; and
      - (2) With respect to fluid-carrying lines, fluid system parts, wiring, air ducts, fittings, and powerplant controls, means the capacity to perform the intended functions under the heat and other conditions likely to occur when there is a fire at the place concerned.
  - No definition of test method, apparatus, or criteria
  - Advisory material has been used to define these test parameters

History of Oil Burners

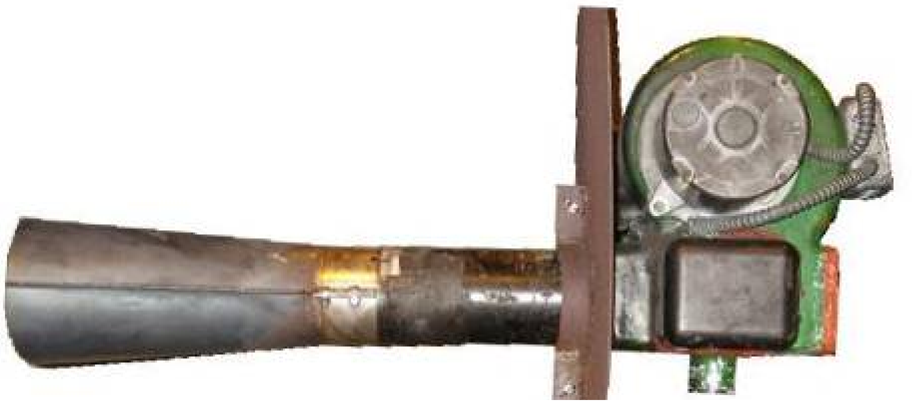
- **The FAA has utilized various forms of a modified home heating oil burner for aircraft material and system fire testing**
  - The flame produced by this type of burner is used to simulate the effects of a severe fire in a controlled laboratory-scale test
- **As aircraft fire safety evolved over the past 50 years, more test methods were developed that employed the oil burner as the test apparatus**
  - Powerplant components and firewalls
  - Cargo compartment liners
  - Seat cushions
  - Thermal acoustic insulation
- **At the same time, the oil burners specified in the regulations went out of production and were no longer obtainable**
  - Newer oil burners were specified and considered equivalent if the required heat flux and temperature could be achieved



Carlin 200 CRD



Lennox OB-32



Park DPL 3400

Evolution

Powerplant Components (1950's)

- Multiple acceptable burners
- Various testing configurations
- Various test materials
    - Metallic components, firewalls, hoses, etc
- Requirements
    - 2000°F, 9.3 BTU/ft^{2}s

Cargo Liner (1984)

- Multiple acceptable burners
- Single testing configuration
- Single test material
    - Thin, flat fire barriers
- Requirements
    - 1700 ± 100°F, 8.0 ±0.5 BTU/ft^{2}s
    - Exit air velocity

Seat Cushion (1984)

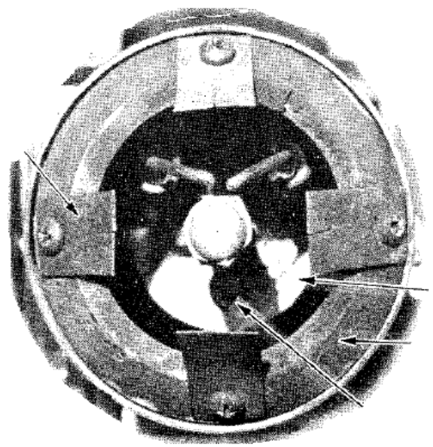
- Multiple acceptable burners
- Single testing configuration
- Single test material
    - Thick, soft cushions
- Requirements
    - 1900 ± 100°F, 10.5 ±0.5 BTU/ft^{2}s

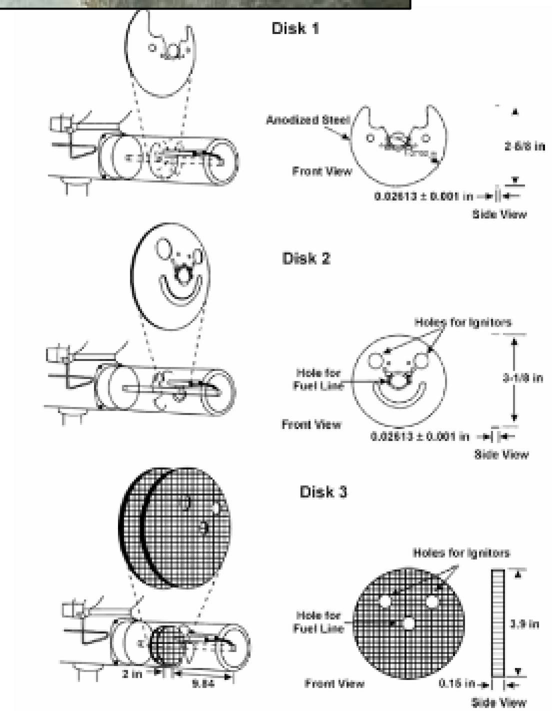
Thermal Acoustic Insulation (2008)

- Single acceptable burner
- Single testing configuration
- Single test material
    - Thin, flexible fire barriers
- Requirements
    - 1900 ± 100°F, 16.0 ±0.5 BTU/ft^{2}s
    - Inlet air velocity

Lessons Learned Over the Years

- **Not all burners are created equal**
- **Configuration of burner components can drastically alter flame**
- **Burner air flow can have a significant effect on test results, especially for lighter weight materials**
- **It's an oil burner, not precision lab equipment!**





Research - Current FAA Documentation

- **Advisory Circulars and FAA Reports:**
  - Power Plant Engineering Report No. 3A, Standard Fire Test Apparatus and Procedure (For Flexible Hose Assemblies), Revised March 1978
    - Acceptable fire test burners listed in Appendix III:
      - Lennox OB-32 (not available)
      - Carlin 200 CRD (not available)
      - Stewart-Warner HPR 250 (not available)
      - Stewart-Warner FR-600 (not available)
  - AC 20-135, Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria, 2/6/90
    - Acceptable fire test burners listed in sec. 6c:
      - Those listed in Appendix III of Powerplant Report 3A
      - SAE 401 Burner adjusted to 9.3 BTU/ft^2s (propane fueled burner)
      - Propane and oxy-acetylene torch-standard and diverging nozzles
  - FAA Aircraft Materials Fire Test Handbook (4/2000)
    - Chapter 11 specifies the oil burners listed above, plus
      - Park DPL 3400 (not available)
    - Chapter 12 specifies the oil burners above, including the Park DPL 3400
      - Chapter 12 Supplement, section 12.3.1 states:
        - » SAE AS401B Propane Burner is also acceptable provided the temperature profile and heat flux density conform to the specified requirements
  - AC 33.17-1A, Engine Fire Protection, 8/3/09
    - References Powerplant Report 3A and AC 20-135 for acceptable burners

Current Status

- **All of the specified oil burners are no longer commercially available**
- **Industry is left with the propane burner, which can be obtained and is typically preferred due to it's consistency and ease of use**
  - Propane and jet fuel flames, despite having similar measured temperatures and heat flux, are fundamentally different
  - Propane will provide a less severe flame than a jet fuel flame, due to the transparency of the propane flame vs. the opacity of the jet fuel flame
    - As test components approach the flame temperature, they begin to re-radiate due to the high surface temperature
    - Heat is lost readily from the hot surface through the transparent propane flame
    - Heat is not lost through the opaque jet fuel flame
  - Intent of regulations is to provide protection against an *engine* fire, which is a jet fuel flame, not a propane flame
- **FAA Tech Center Fire Safety Team has been tasked by Transport Airplane Directorate to develop burner performance standards for the next-generation fire test burner for powerplant fire testing**

Genesis of the Next Generation Fire Test Burner

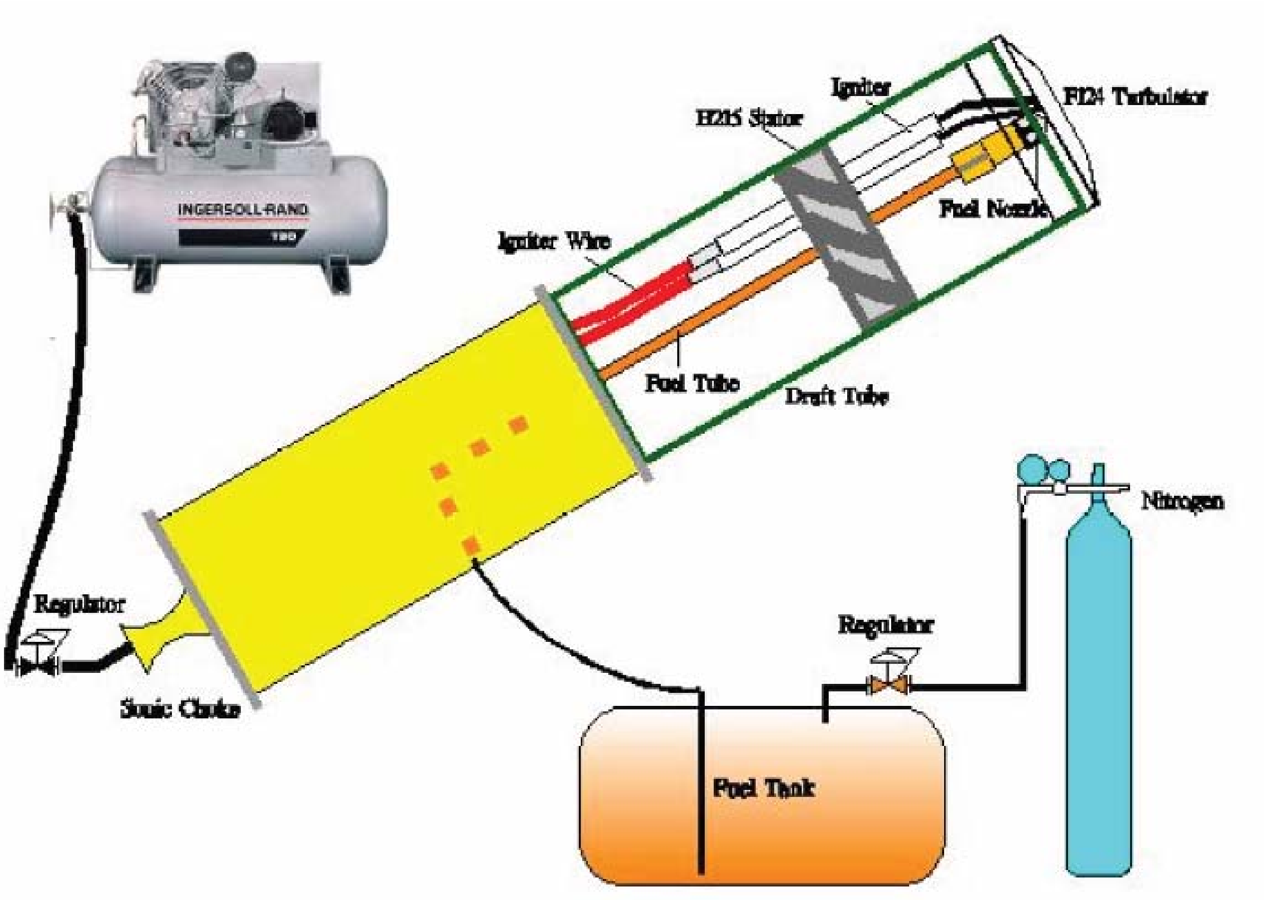
- **During development and implementation of the Thermal Acoustic Insulation Burnthrough Rule, it was discovered that the Park DPL 3400 was no longer in production**
- **Options**
  - Find another commercial off the shelf oil burner
  - Develop a new burner that will not suffer the same fate

Objectives

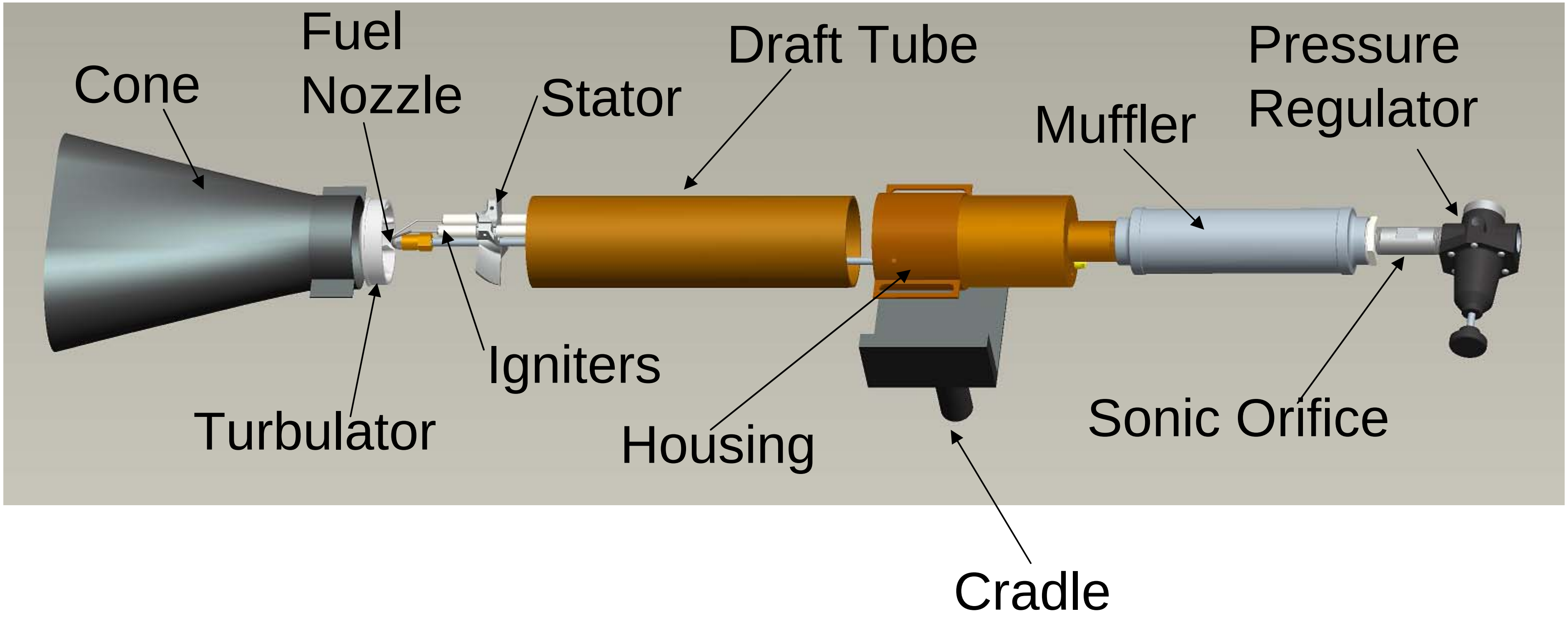
- **Design a fire test burner that can be constructed in-house with easily obtainable components**
  - Simple design
  - Simple operation
  - Simple maintenance
- **Burner output must be comparable to the Park DPL 3400**
- **Burner should achieve a higher level of repeatability and reproducibility**
- **Burner should be versatile and easily adaptable to any of the fire tests calling for a "modified gun-type burner"**

Initial Concept

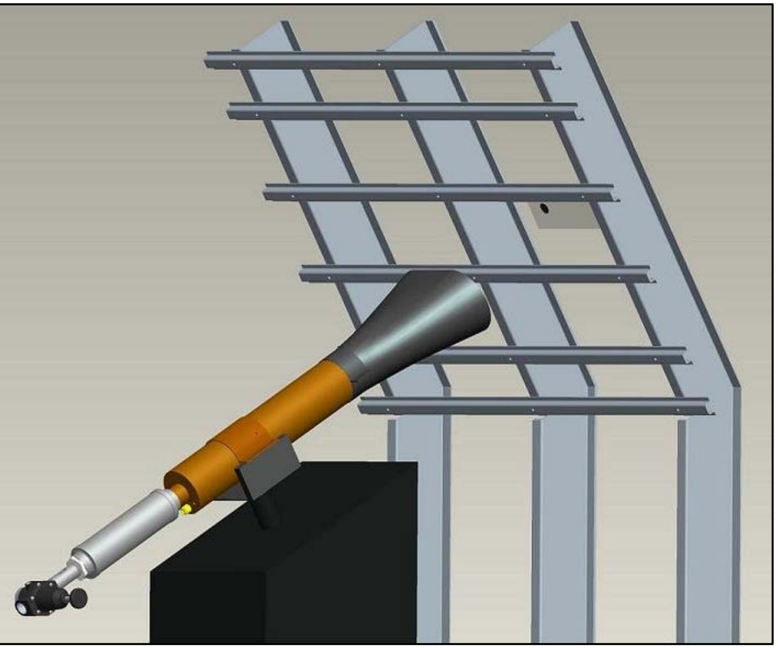
- **Compressed air metered with a sonic nozzle**
- **Fuel provided by a pressurized fuel tank**
- **Utilize original Park DPL 3400 components**



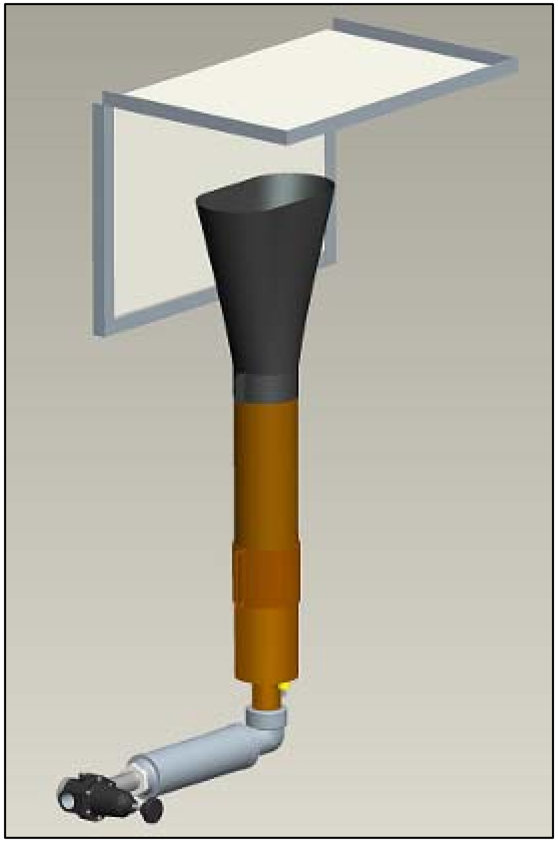
NexGen Burner Design



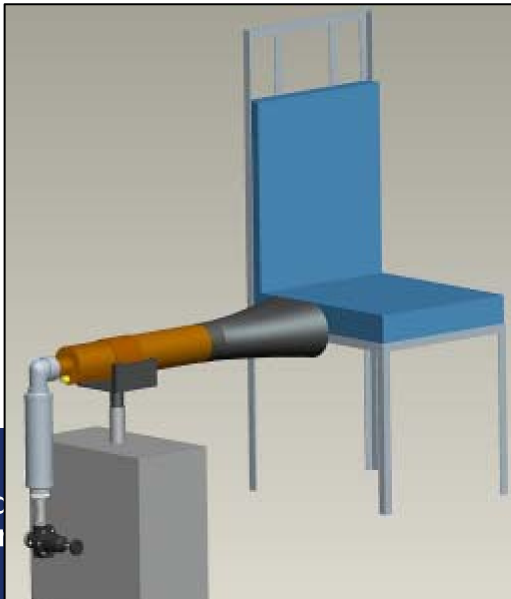
Thermal/Acoustic Insulation Burnthrough



Cargo Liner Burnthrough



Seat Cushion Flammability

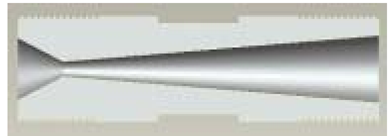


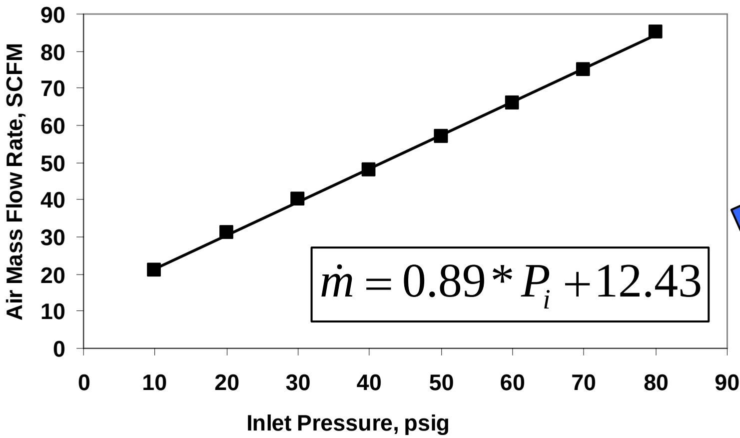
Burner Control

Air Flow

+

+





Fuel Flow

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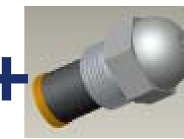
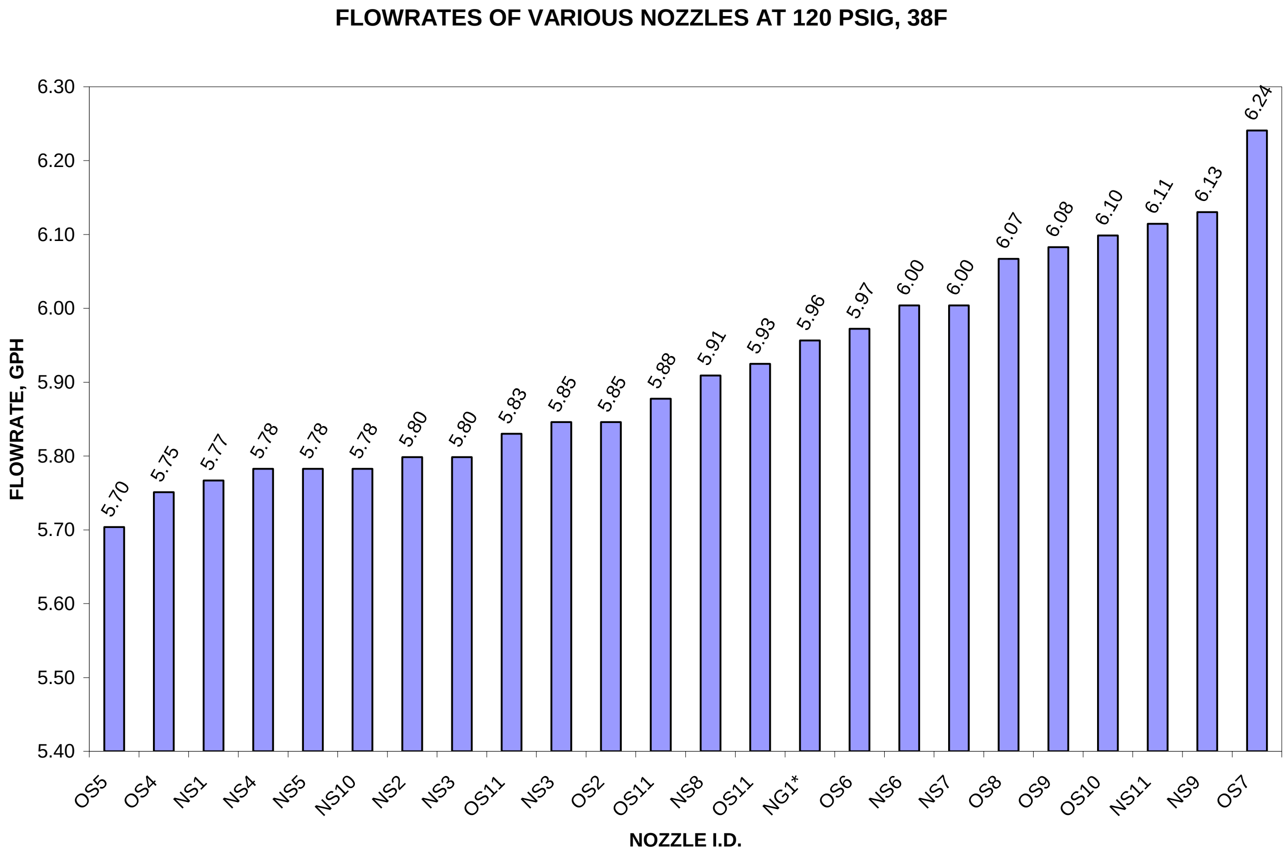
+



Regulated and conditioned air and fuel to burner

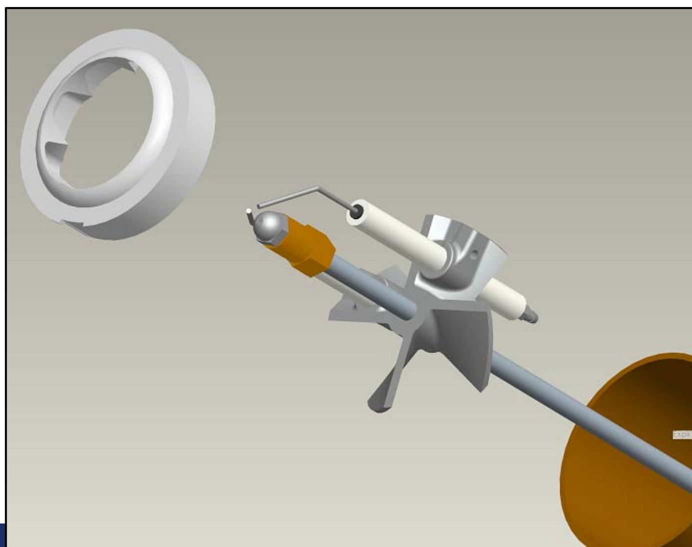
Spray Nozzles

- **Fuel flow rate depends on test method**
  - 2.0 gph
    - Powerplant
    - Cargo liner
    - Seat cushion
  - 6.0 gph
    - Thermal acoustic insulation
- **Nozzles are standard oil burner fuel spray nozzles**
- **Manufacturing consistency OK for oil burners, not lab equipment**
- **Measured flow rate depends on:**
  - Particular nozzle
  - Fuel pressure
  - Fuel Temperature
- **Before a nozzle is selected for installation, it must be flow checked at the operating temperature and pressure**



Components

- A working group participant was able to digitize the original stator and turbulator
- They were able to correct irregularities and asymmetries in design software
- A computer numerical controlled (CNC) mill was used to cut new, corrected stators and turbulators
- Comparison testing validated the performance of the new components



Original Turbulator

Prototype Turbulator

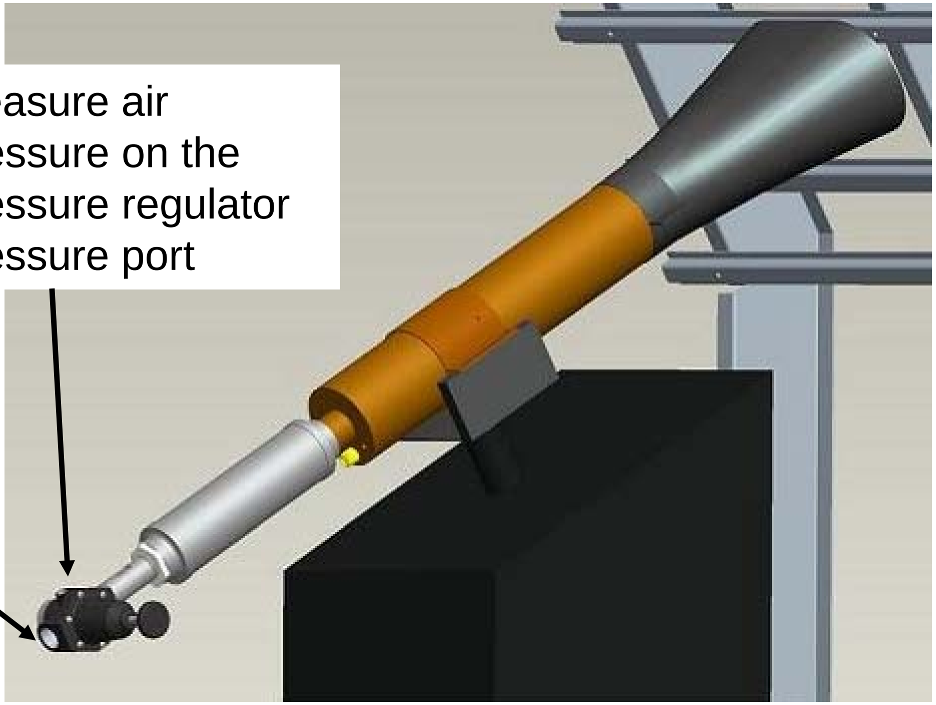
Original Stator

Prototype Stator

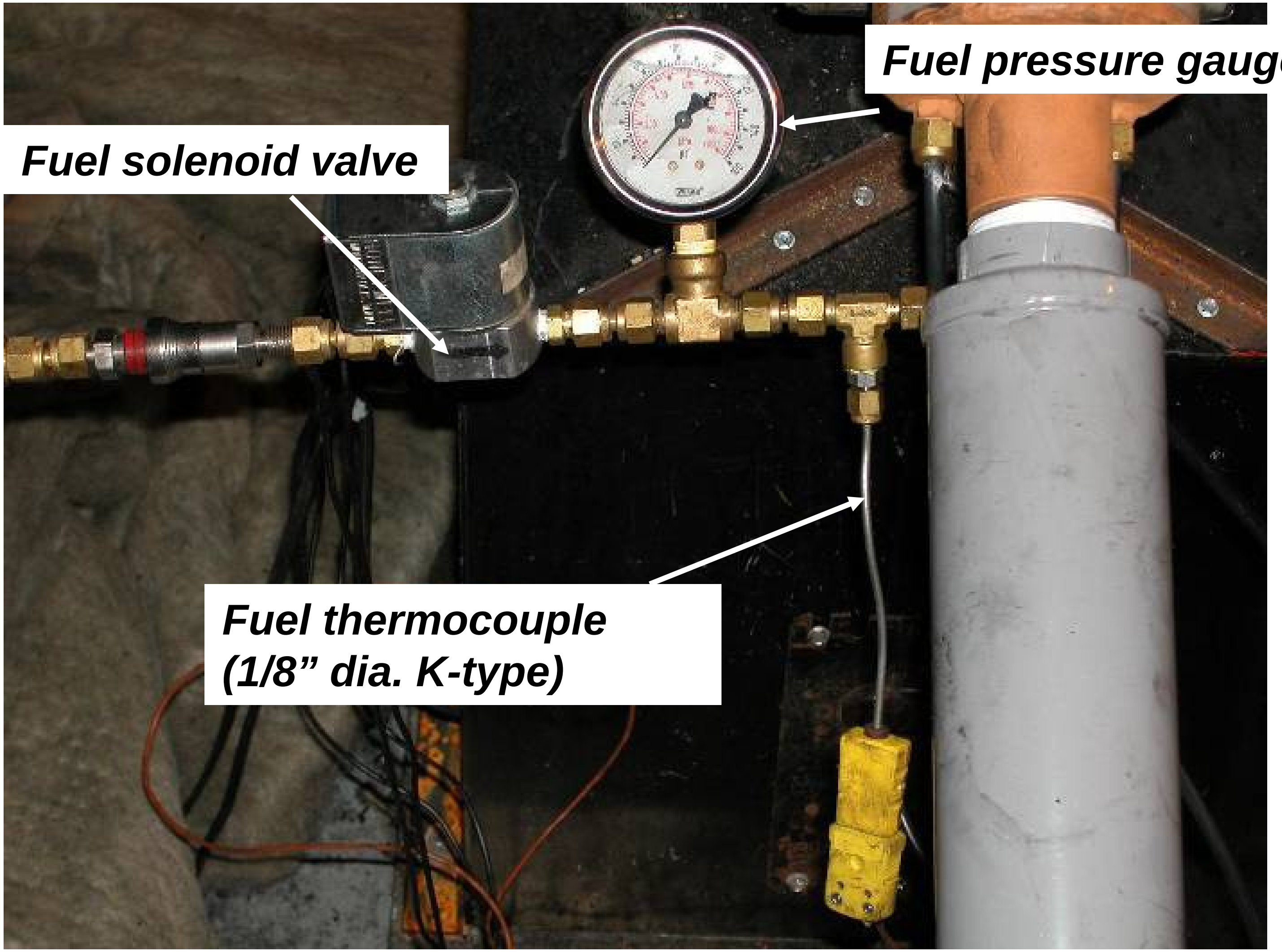
Air Measurement

Measure air temperature just upstream of the pressure regulator with a 1/8” K-type thermocouple

Measure air pressure on the pressure regulator pressure port

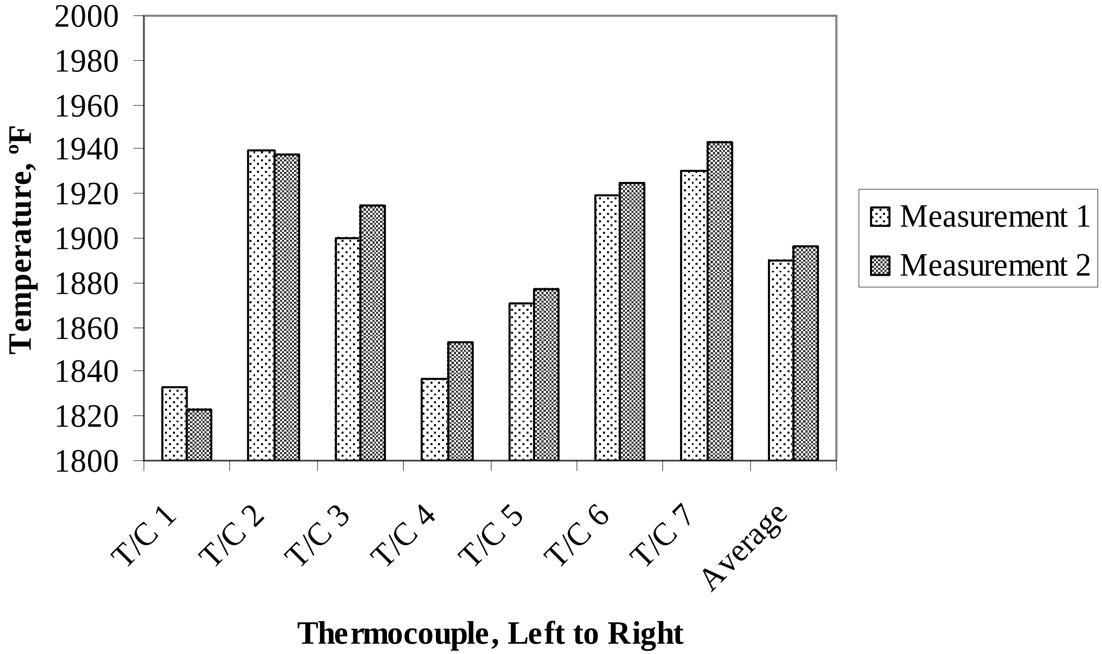


Fuel Measurement



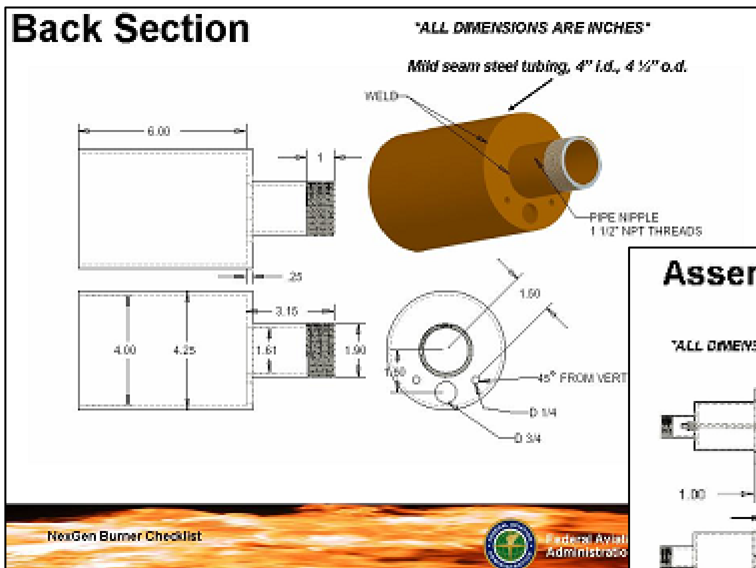
Burner Performance

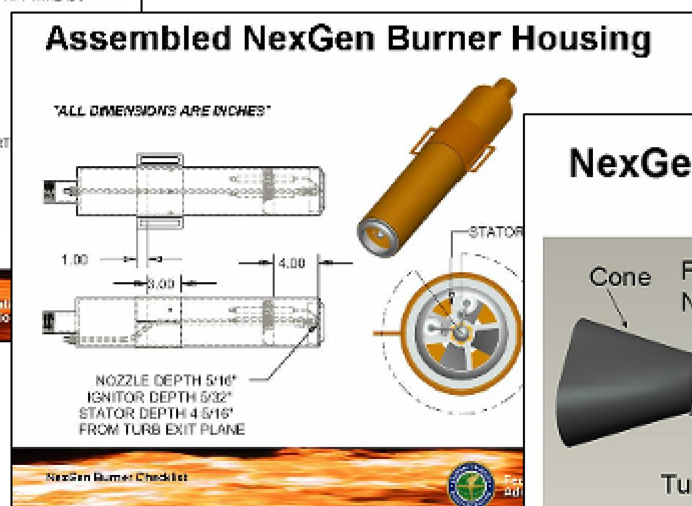
- **Burner operational parameters depend on the test being performed**
  - Powerplant, Cargo Liner, Seat Cushion
    - 2.0 gph fuel flow rate
  - Thermal Acoustic Insulation Burnthrough
    - 6.0 gph fuel flow rate

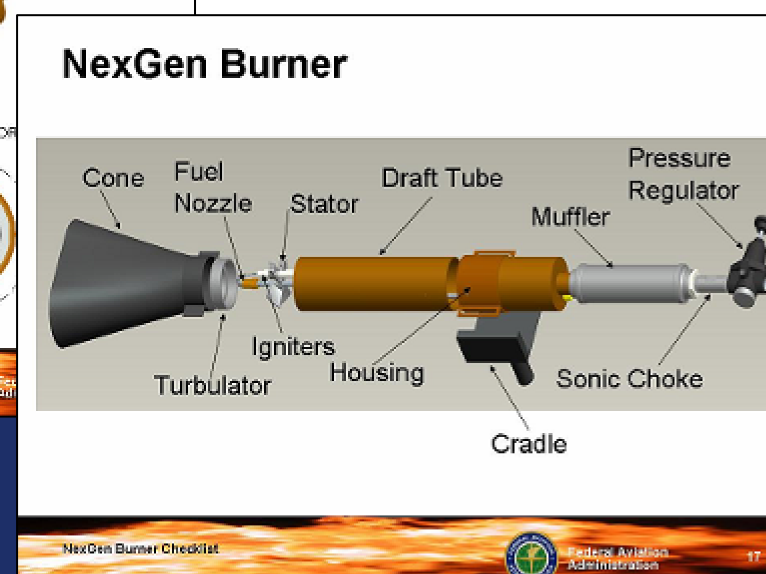


NexGen Drawings

- **Drawings are available online at**
  http://www.fire.tc.faa.gov/pdf/materials/NexGenPlans.pdf







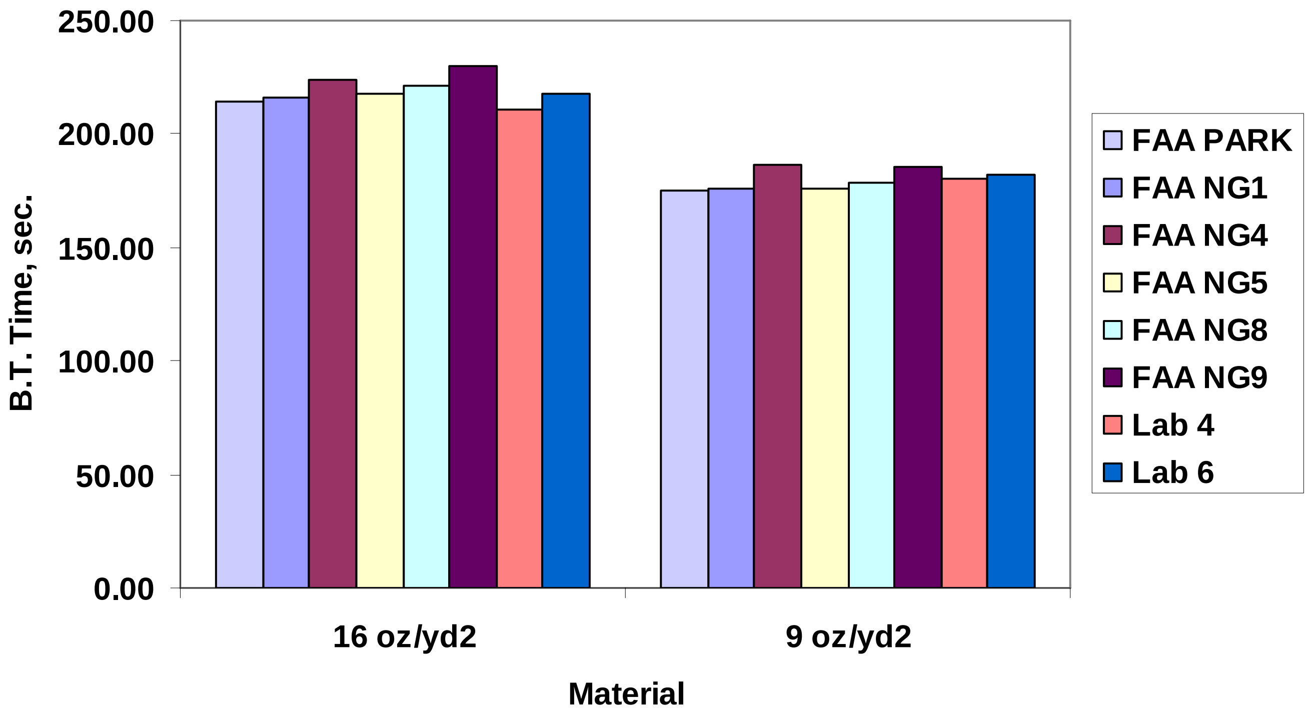
NexGen Burner Calibration

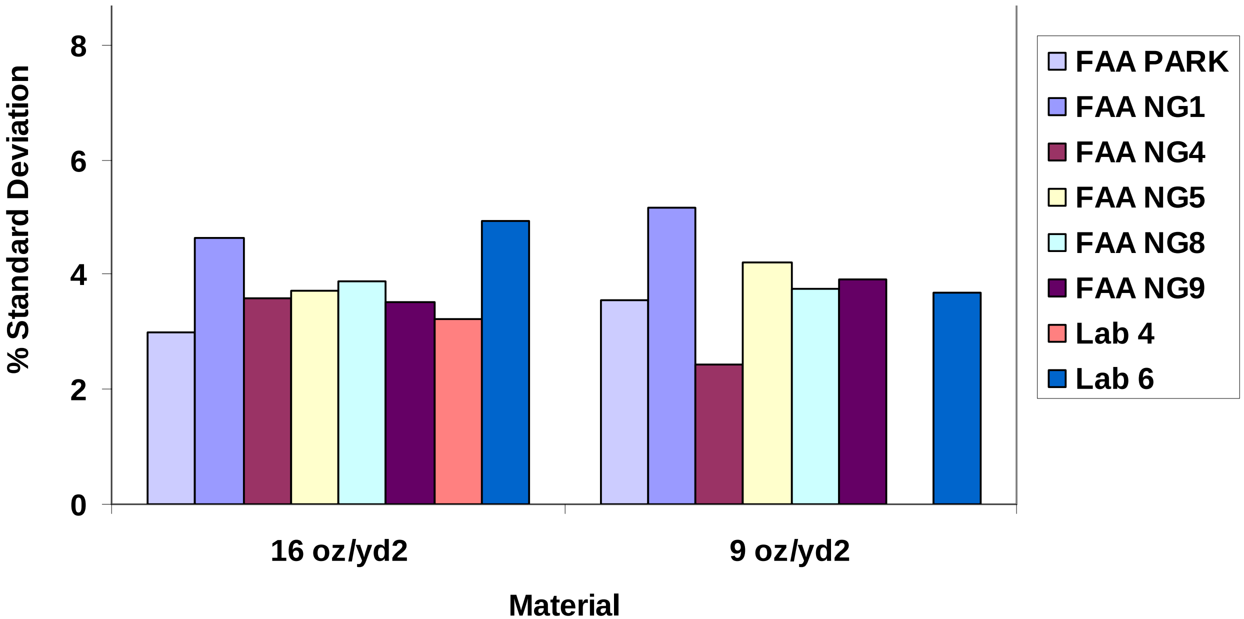
- **For the NexGen burner, the heat flux measurement has been removed from the calibration procedure**
  - Heat flux transducers measure instantaneous heat flux at a very small point in the flame
  - Specifically, Gardon gauges were designed and are intended for measuring intense thermal radiation only
    - Use in an intense, mixed-mode heat transfer environment introduces significant measurement uncertainty
  - Since all inlet parameters and burner dimensions are fixed, no adjustments can be made to achieve a specified heat flux
- **Flame temperature is measured and used to determine proper burner output**
  - 1/8” S.S. sheathed ceramic packed K-type thermocouples
- **Ultimate test of similarity between Park DPL 3400 and NexGen was comparative burnthrough and seat cushion testing**
  - Polyacrylonitrile (PAN) fabric material of 2 different densities was chosen due to their typical burnthrough times
    - 16 oz/yd^2 ~ 4 min. BT
    - 9 oz/yd^2 ~ 3 min. BT
    - 25.856b pass/fail criteria is 4 min BT resistance
  - A “picture-frame” sample holder was created to hold material
  - Tests were performed on the Park DPL 3400 and several NexGen burners at different labs

Validation Testing - Burnthrough

Results

- NexGen burners were shipped out to participating laboratories in order to determine the repeatability of the test results in various environments
- Very good agreement was found between labs 4 and 6 and the rest of the NexGen's tested at the FAATC
- All labs and burners were found to have less than 5% relative standard deviation, indicating good repeatability
- Labs 4 and 6 were approved by their respective A.C.O.'s to perform certification tests according to the rule



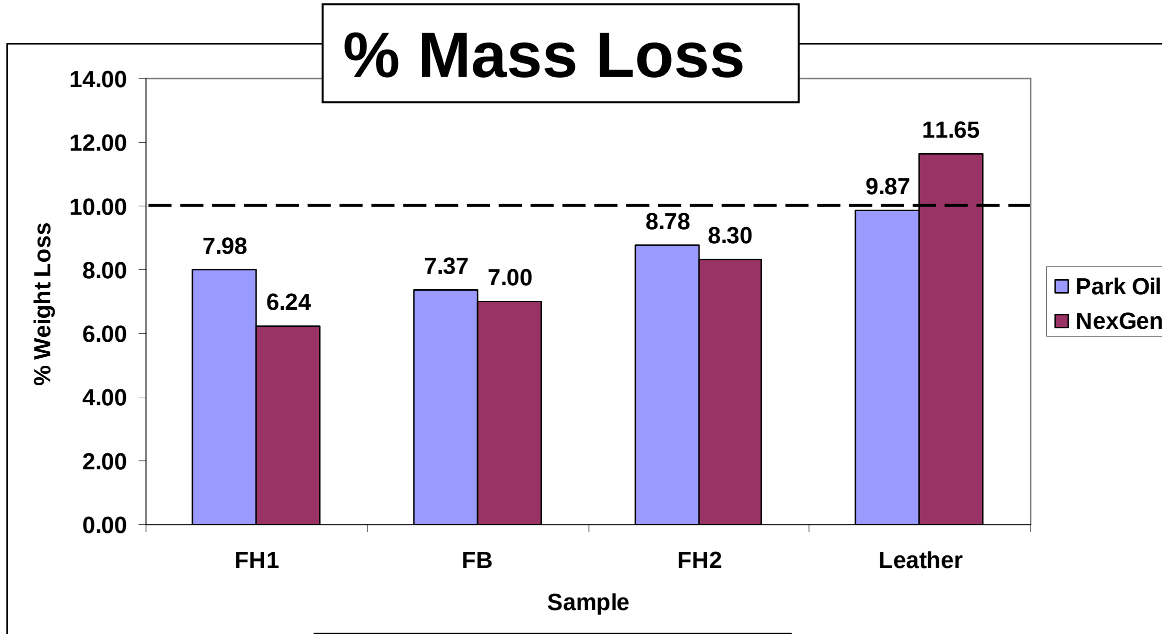


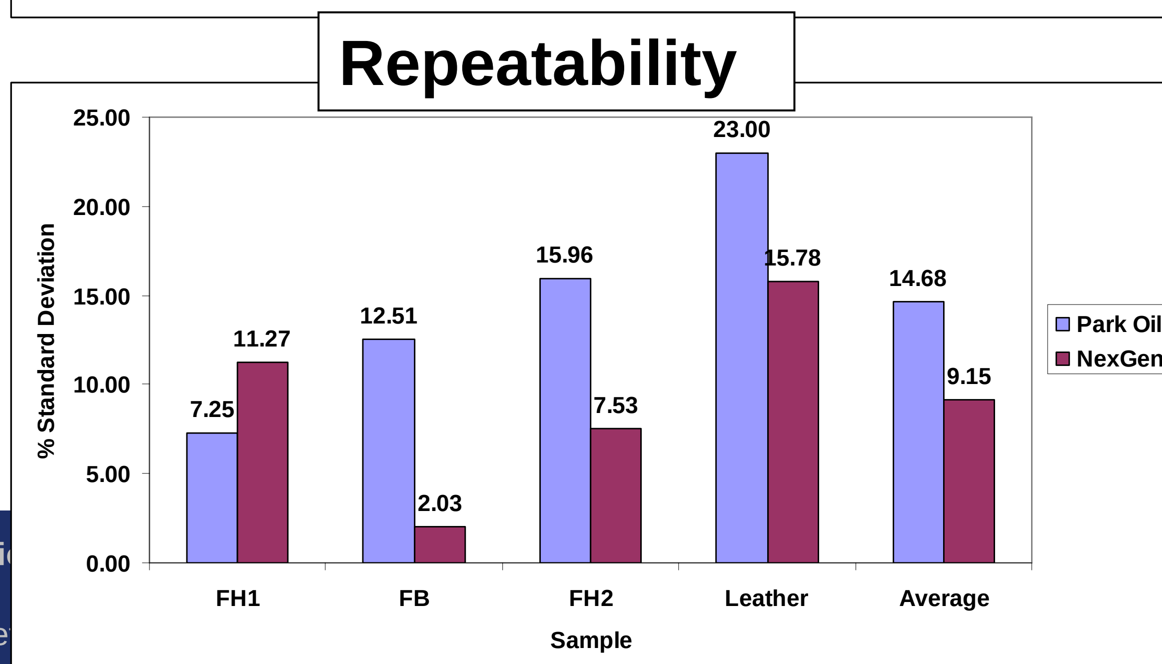
Validation Testing – Seat Cushion

Figure 1. Fire-Hardened Foam 1

Figure 2. Fire-Blocking Layer

Figure 3. Fire-Hardened Foam 2





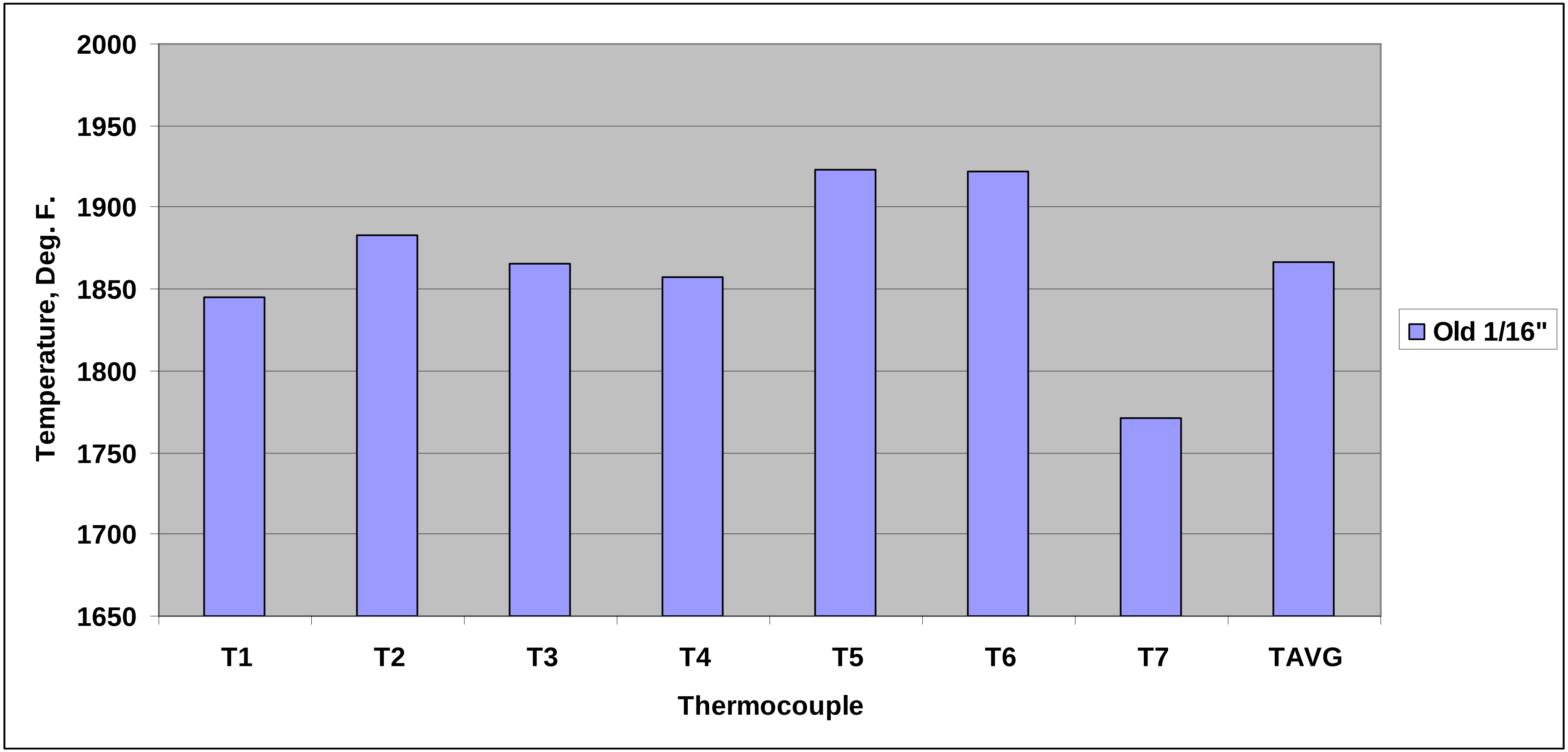
Application of NexGen Burner to Powerplant Fire Testing

- **Slight modifications to be made:**
  - Burners specified in AC 20-135 are based on the 2.0 gph fuel flow rate
    - Same burner for the seat test (25.853) and cargo liner burnthrough (25.855), which is a 2.0 gph fuel flow rate nozzle and lower air flow rate than the burnthrough burner
  - Currently, FAATC is near completion of developing NexGen burner operating parameters for the seat test
    - Configured a NexGen burner to achieve seat test performance similar to a Park DPL 3400 calibrated to standards set in chapter 7 of the Aircraft Materials Fire Test Handbook
      - Fuel flow rate of 2.0 gph ± 0.1 gph
      - Equivalent to an inlet air flow of 67 ± 4 cfm
      - Flame temperatures of at least 1800°F on 5 of 7 thermocouples and at least 1750°F on at most 2 thermocouples
      - 30-second average of 7 thermocouples at least 1800°F

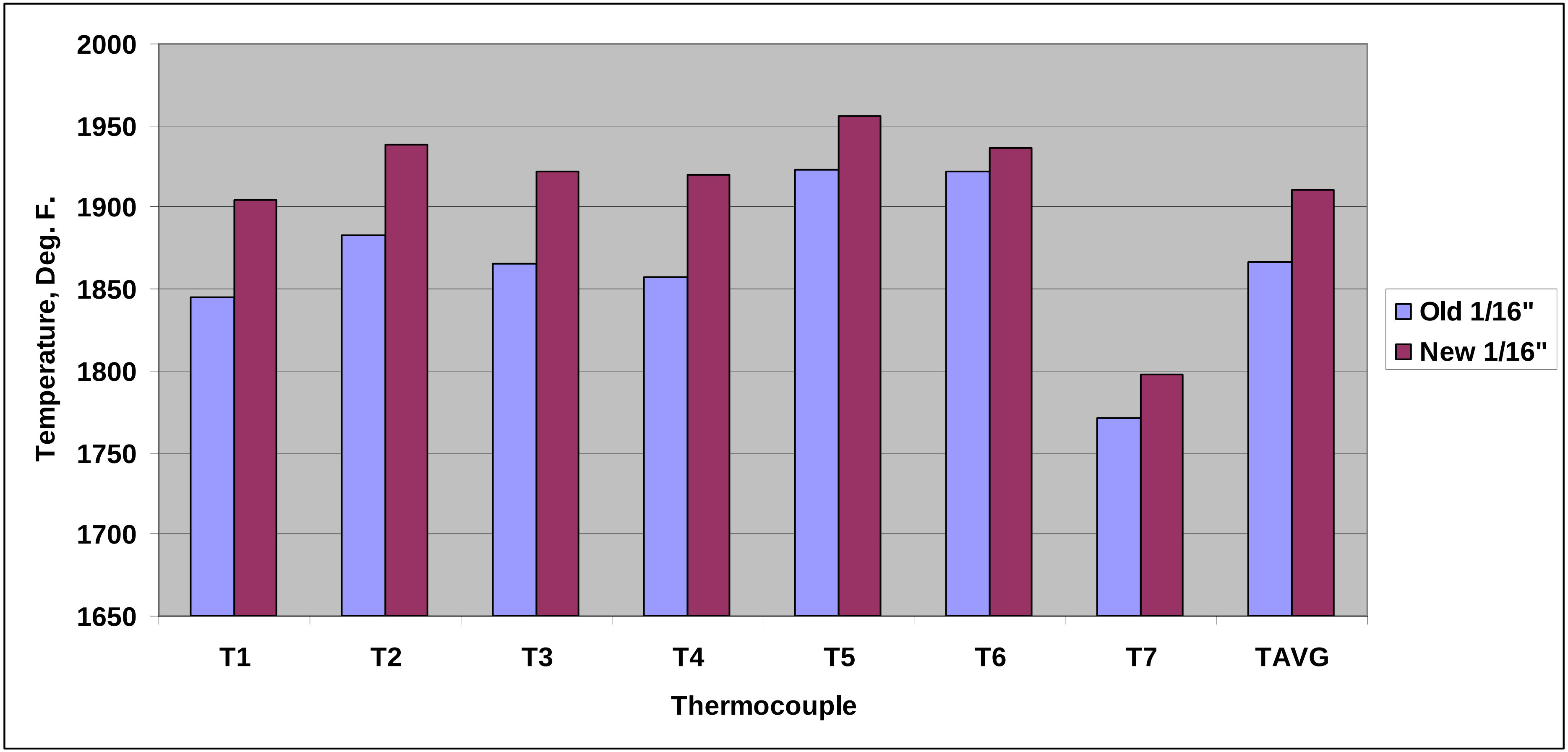
Flame Temperature Measurement

- **Tests were performed to determine the effect of the thermocouple on the measured flame temperature**
  - 1/16” ss sheathed ceramic packed K type TC
    - Old
    - New
  - 1/8” ss sheathed ceramic packed K type TC
    - New
  - 1/8” ss sheated ceramic packed K type TC
    - Exposed Junction
    - New

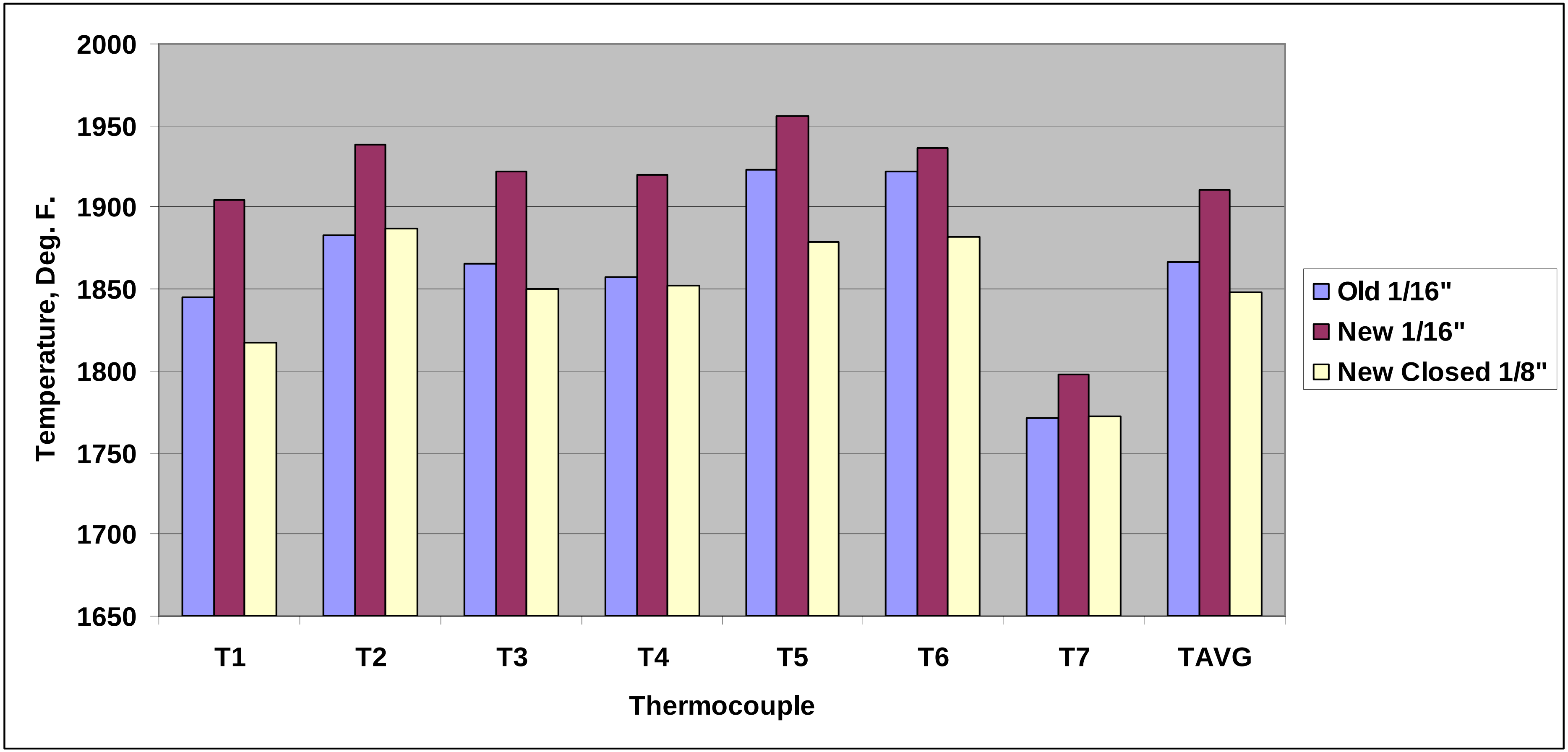
Thermocouple Effects



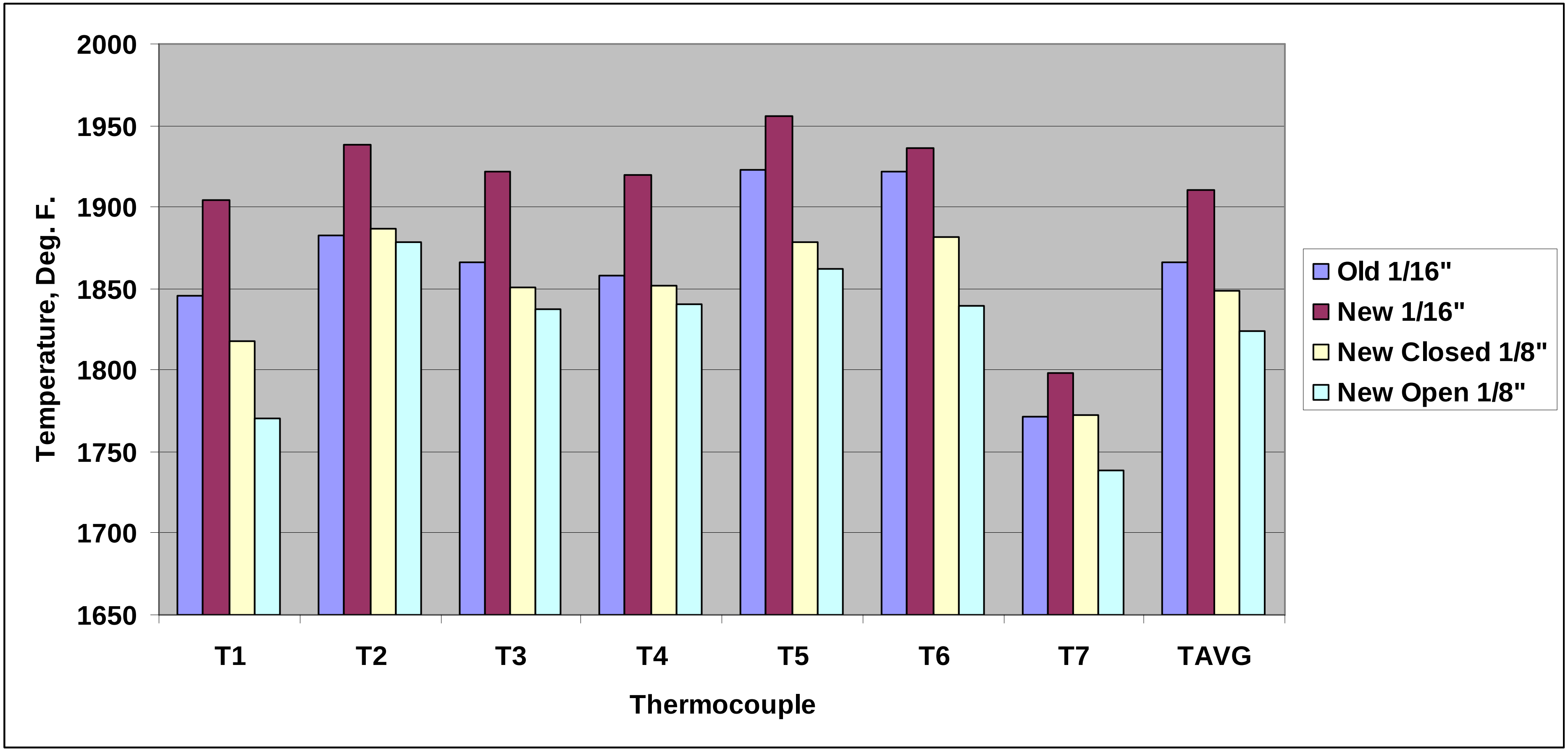
Thermocouple Effects



Thermocouple Effects



Thermocouple Effects



Thermocouple Effects - Summary

- **Thermocouple size, construction, and age all have an effect on the measured flame temperature**
  - 1/16" sheathed TC's had the highest measured temperature, although their accuracy degrades quickly
  - 1/8" sheathed TC's had a lower temperature measurement than both old and new 1/16" TC's
  - 1/8" exposed junction TC's had the lowest temperature measurement of all TC's
- **Although there was an average flame temperature variation of about 100°F, the burner settings remained constant (same flame for all tests)**
  - Specification of an "absolute" flame temperature is not the proper way to define the severity of the flame
  - Measured flame temperature should be used as a guide, and should have broad tolerance, i.e. 2000°F ± 150°F when measured with a specified TC type at a specified location in flame
  - Burner performance should be determined through comparative testing of materials or components
    - FAR's use performance of steel and aluminum to define fireproof and fire resistant

Next Steps

- **Perform comparative testing between a calibrated Park DPL 3400 burner, propane burner, and a 2.0 gph NexGen burner**
  - Use metallic components, hoses, firewalls for comparative testing
  - Perform round-robin style testing with different burners and labs
    - Determine overall average level of severity industry-wide
    - Determine what a realistic “severe engine fire” should be
- **Develop guidance material that includes the NexGen burner**
  - Harmonization with EASA and other regulatory agencies critical to FAA efforts

Questions?

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