Federal Aviation Administration

The Seventh Triennial International Fire & Cabin Safety Research Conference

The Adaptation of the Sonic Burner for the Cargo Liner and Seat Cushion Flammability Tests

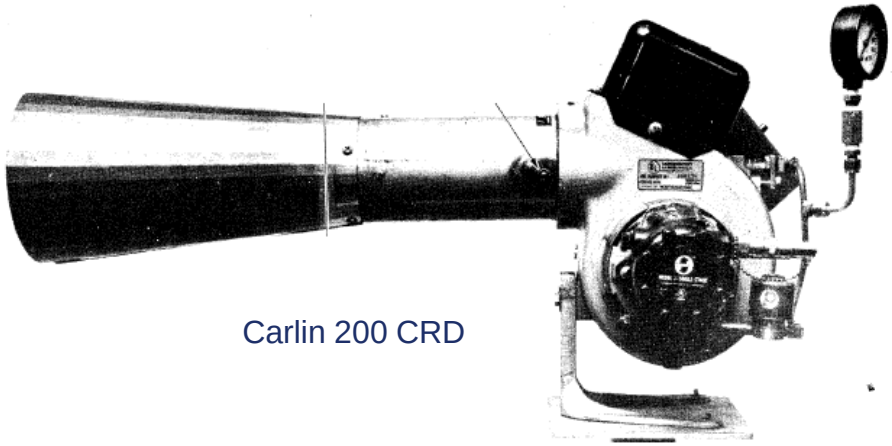
Presented to: The Seventh Triennial International Fire and Cabin Safety Research Conference

By: Tim Salter, FAA Technical Center

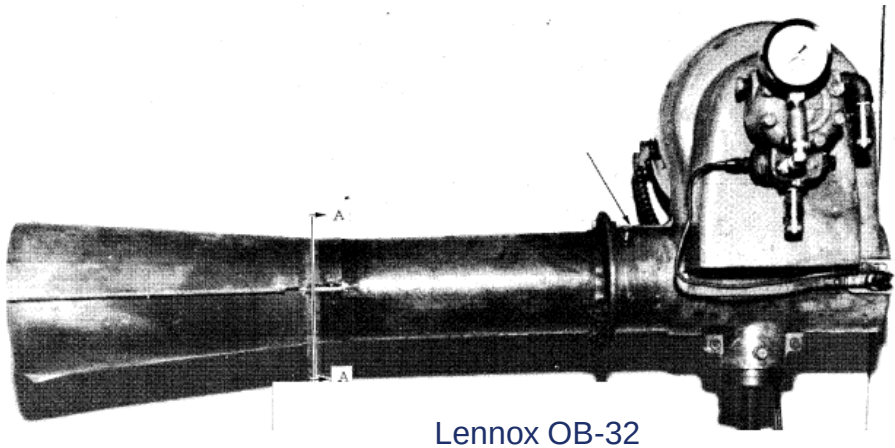
Date: December 2-5, 2013, Philadelphia, PA

Introduction

- **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)

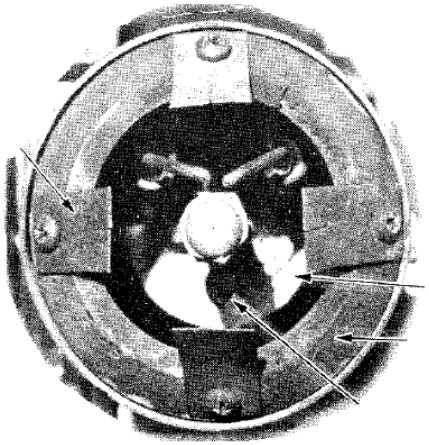
- Multiple acceptable burners
- Single testing configuration
- Single test material
  - Thick, soft cushions
- Requirements
  - 1900 ± 100°F, 10.5 ±0.5 BTU/ft^{2}s

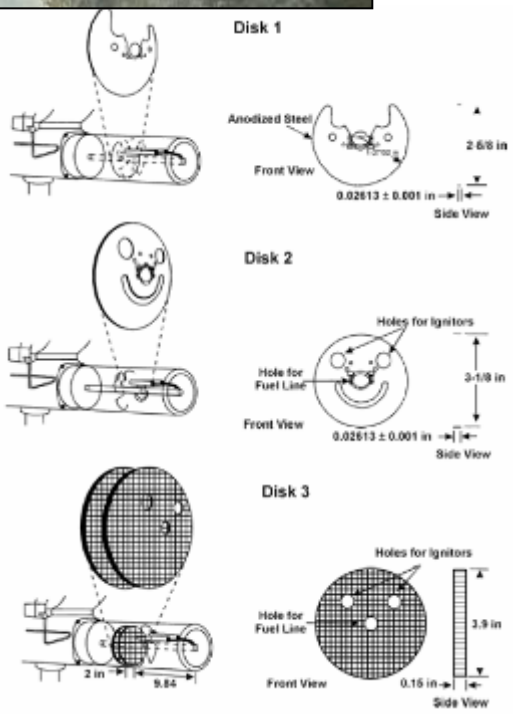
Thermal Acoustic Insulation (2008)

- 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!**





Genesis of the Next Generation Fire Test Burner

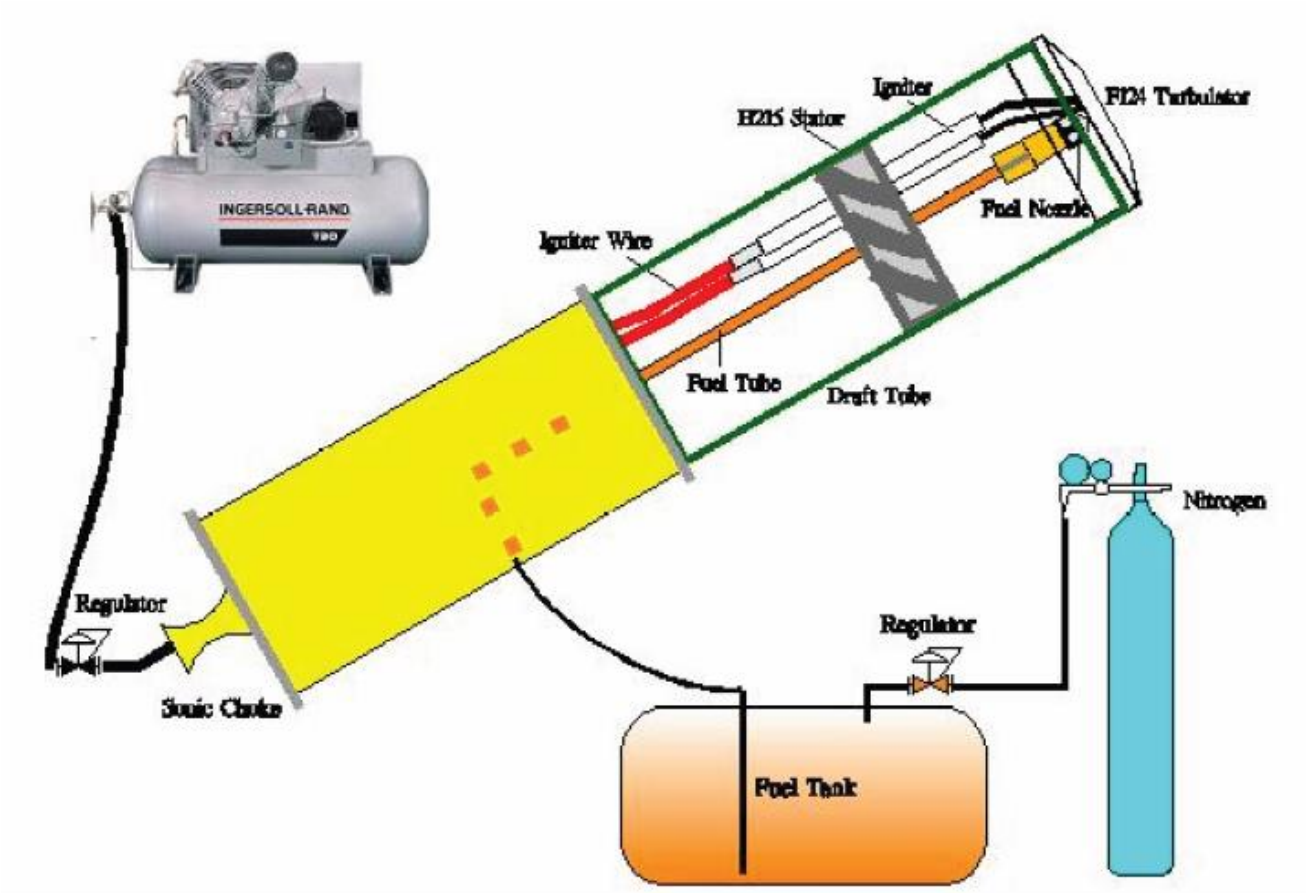
- **During development and implementation of the Thermal Acoustic Insulation Burnthrough Rule, it was discovered that the Park DPL 3400 was no longer in production**
- **Options**
  - Find another commercial off the shelf oil burner
  - Develop a new burner that will not suffer the same fate

Objectives

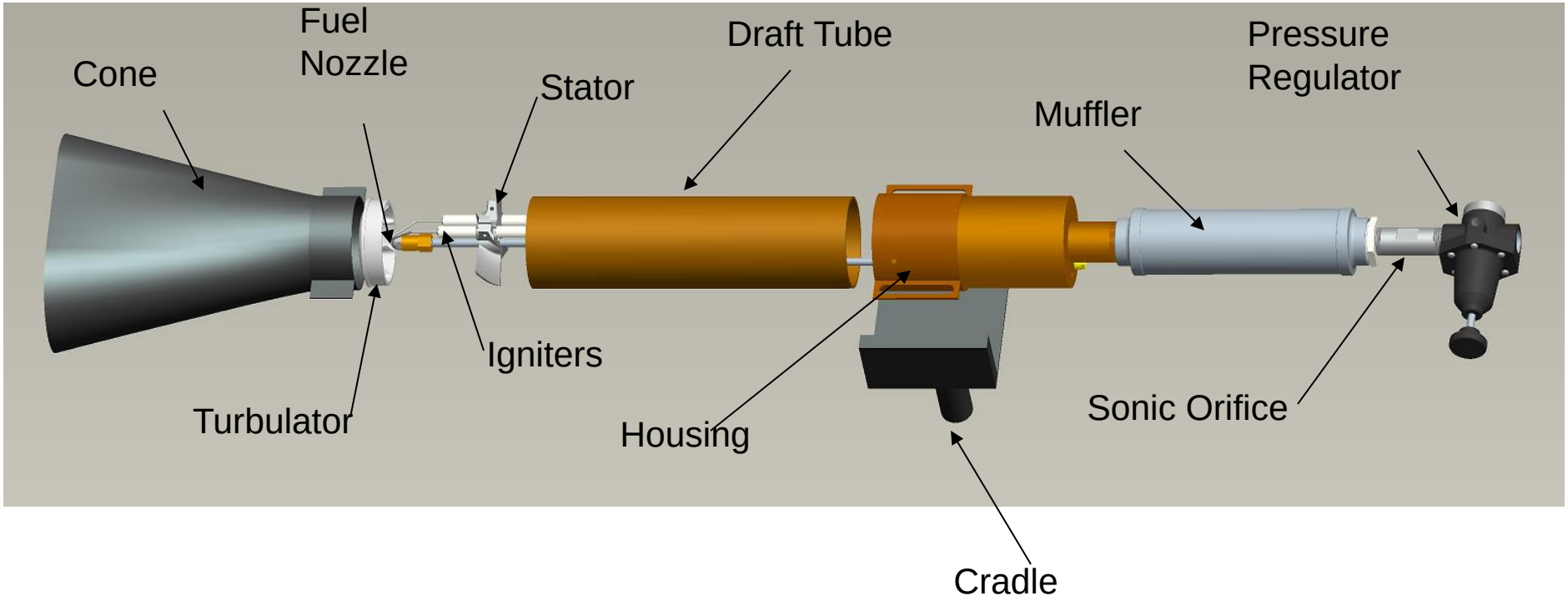
- **Design a fire test burner that can be constructed in-house with easily obtainable components**
  - Simple design
  - Simple operation
  - Simple maintenance
- **Burner output must be comparable to the Park DPL 3400**
- **Burner should achieve a higher level of repeatability and reproducibility**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

Initial Concept

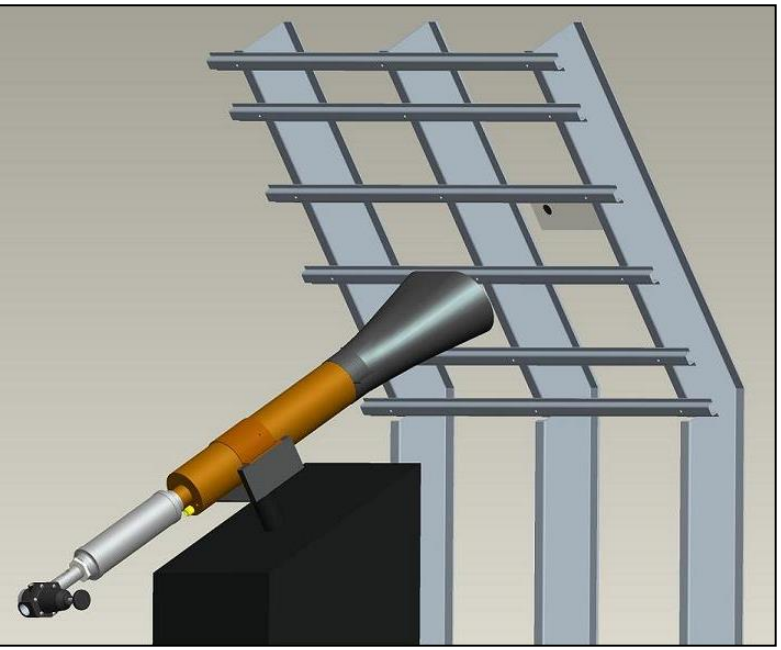
- **Compressed air metered with a sonic nozzle**
- **Fuel provided by a pressurized fuel tank**
- **Utilize original Park DPL 3400 components**



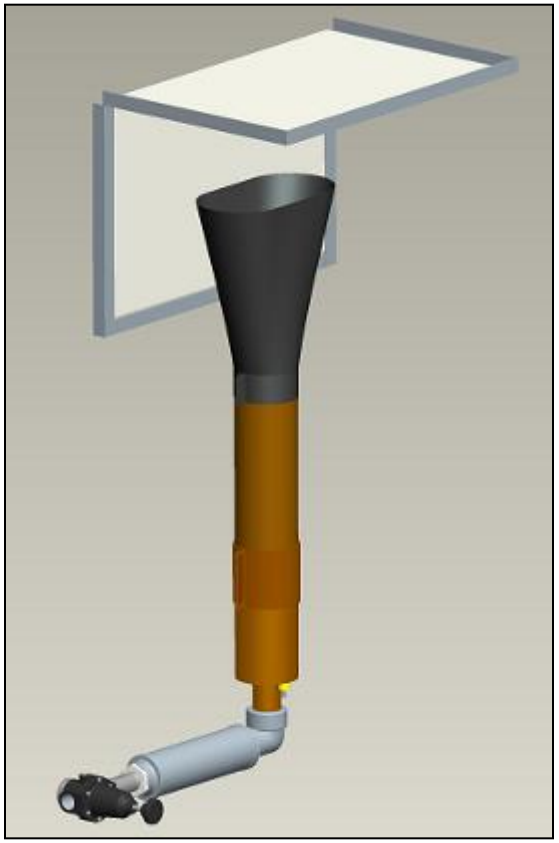
NexGen Burner Design



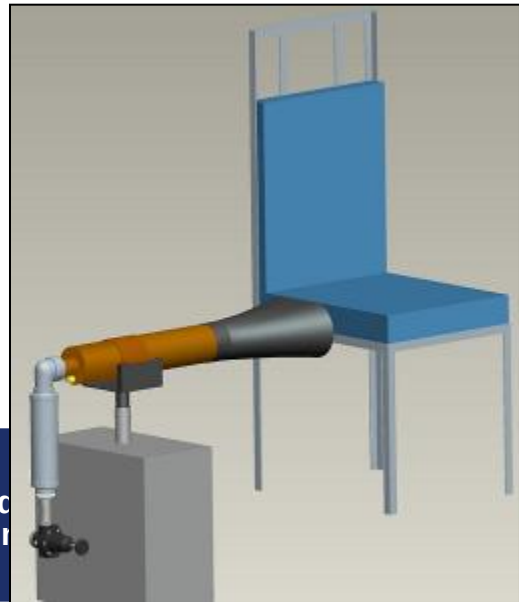
Thermal/Acoustic Insulation Burnthrough



Cargo Liner Burnthrough



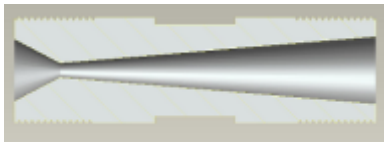
Seat Cushion Flammability

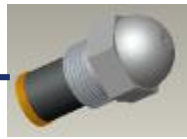


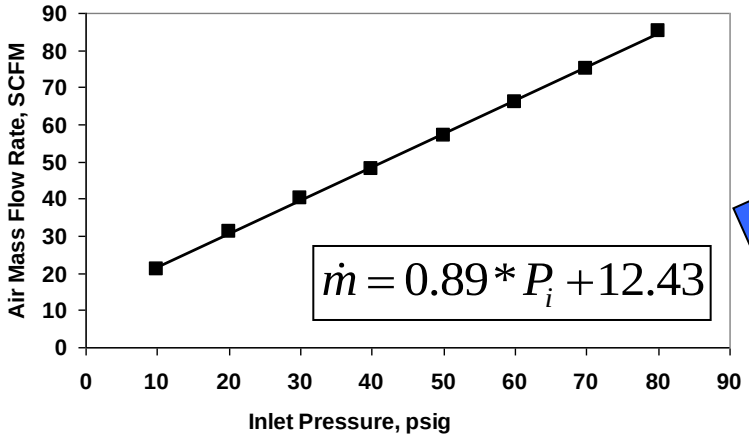
Burner Control

Air Flow

Fuel Flow







Regulated and conditioned air and fuel to burner

Air and Fuel Cooling System

Components

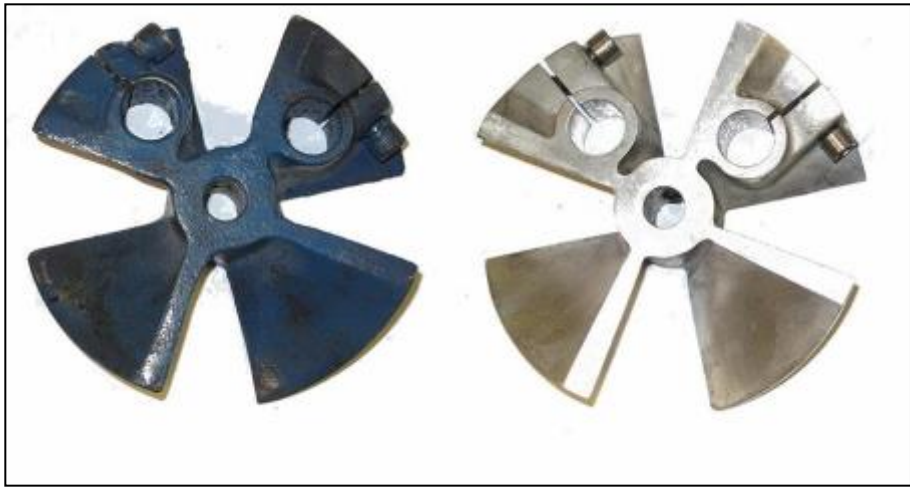
- A working group participant was able to digitize the original stator and turbulator
- Noticing the irregularities in the originals, they were able to correct it in design software
- A computer numerical controlled (CNC) mill was used to cut new, corrected stators and turbulators
- Comparison testing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

Original Turbulator

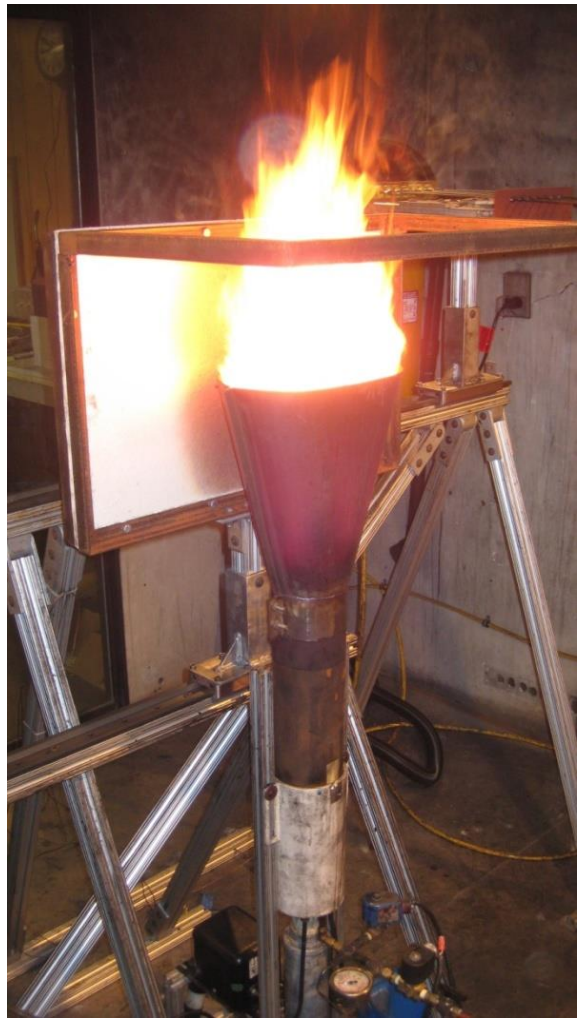
Prototype Turbulator

Original Stator

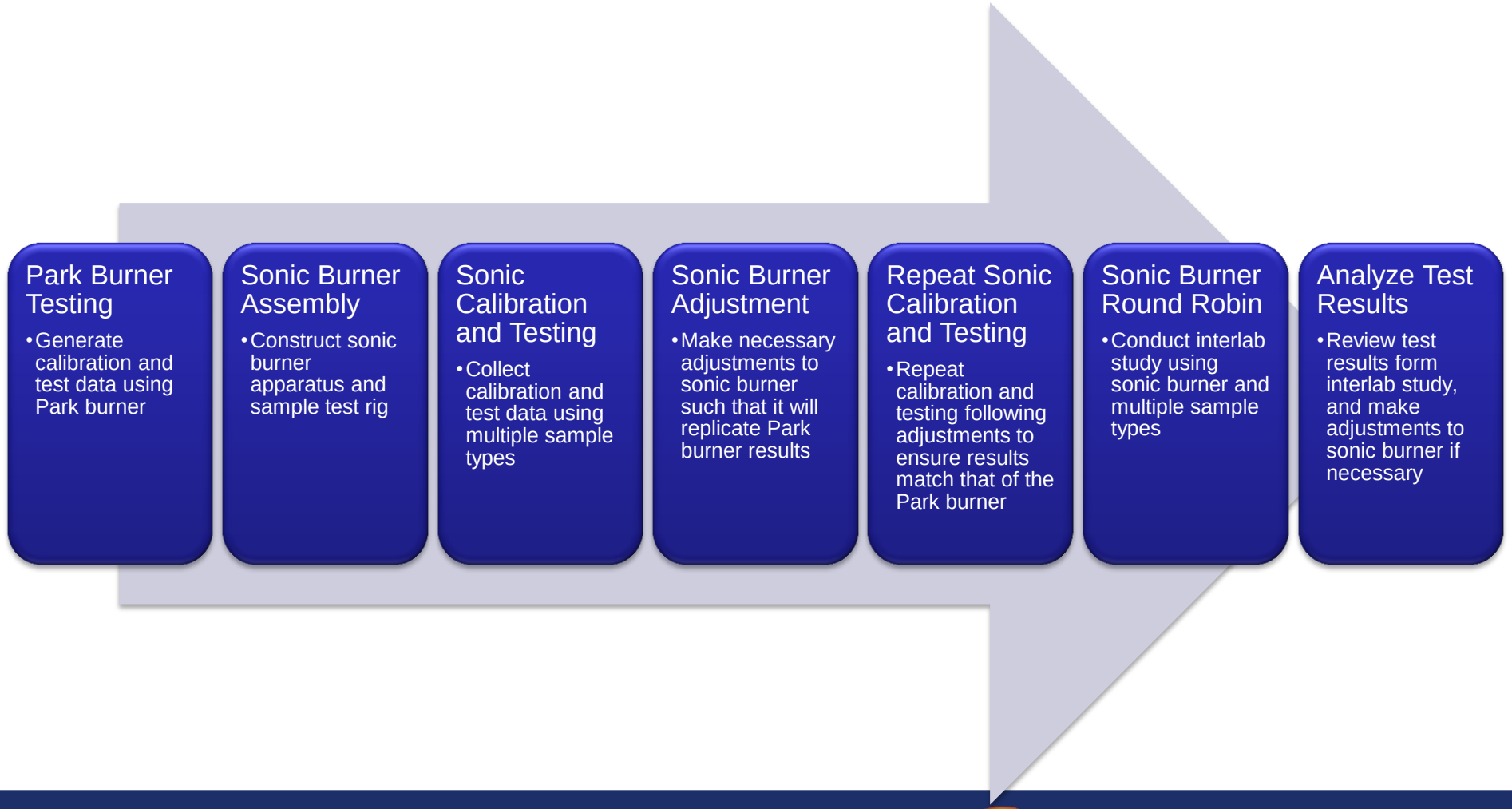
Prototype Stator



Main Objective: Transition from Park Burner to Sonic Burner



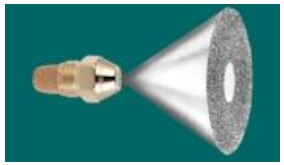
Burner Transition Plan for Cargo Liner and Seat Cushion Flammability Tests

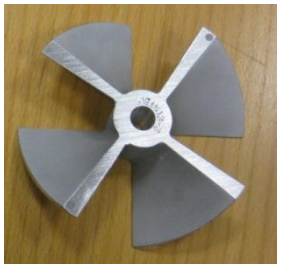


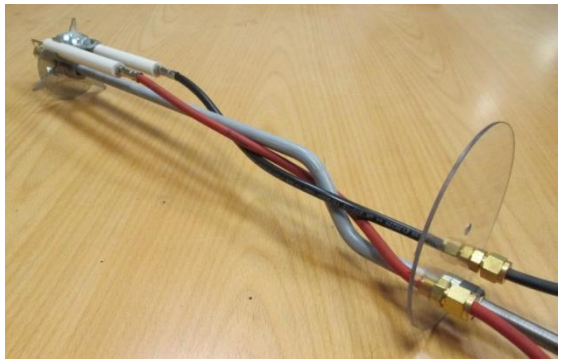
NexGen Burner Adjustment and Testing

- **Adjustments for both cargo liner and seat cushion NexGen burners**

- **Fuel Nozzle Type**
  - Flow rate and spray pattern
- **Fuel Nozzle Depth**
  - Distance from exit plane of burner
- **Stator Position**
  - Axial and rotational position on fuel rod
- **Ignition Wires**
  - Length, location, and path within burner tube
- **Igniters**
  - Location in relation to each other and nozzle







- **Final settings unique to each NexGen burner**

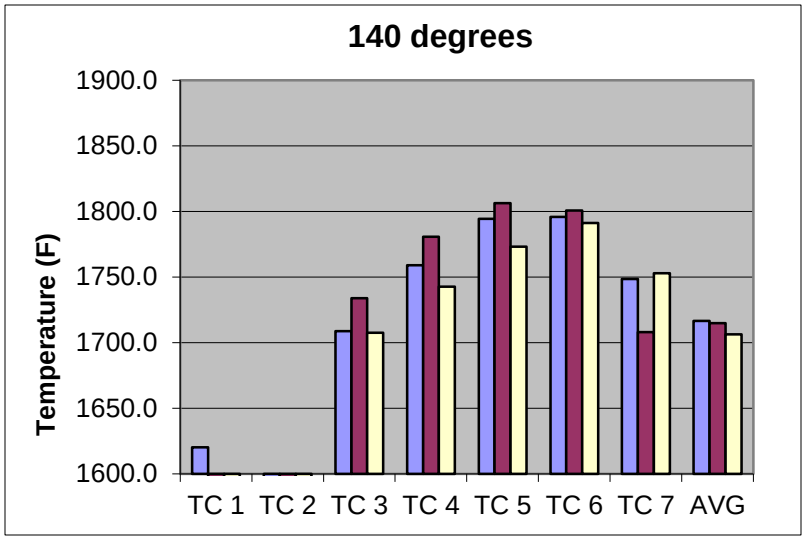
Fuel Nozzle Selection

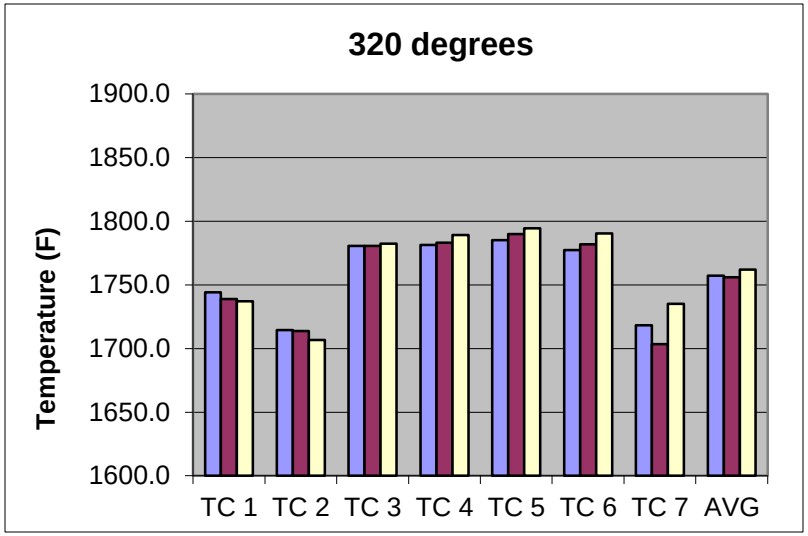
- **Previously, Monarch nozzles recommended for use in both the 2.0 GPH cargo liner and seat cushion oil burners**

- **Testing and study showed Monarch nozzles often produced a nonuniform spray pattern leading to a flame that is more biased to one side or another**
  - Calibration tests (shown in graphs) would tend to show higher temperatures bias to one when the fuel nozzle was rotated to certain angles

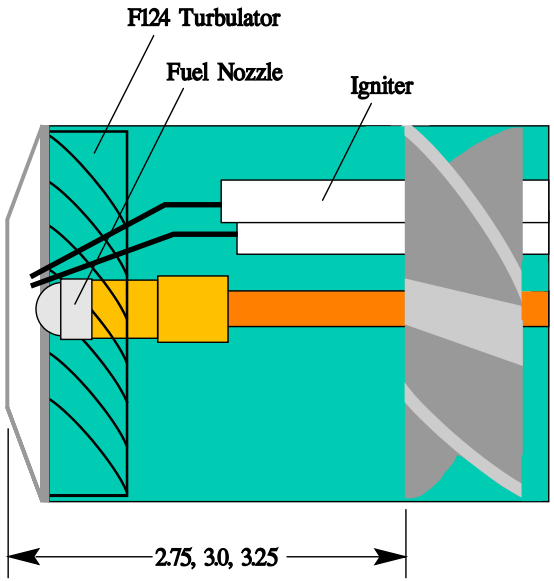
- **Flow testing also proved that measured flow rates did not match the rating of the fuel nozzle**

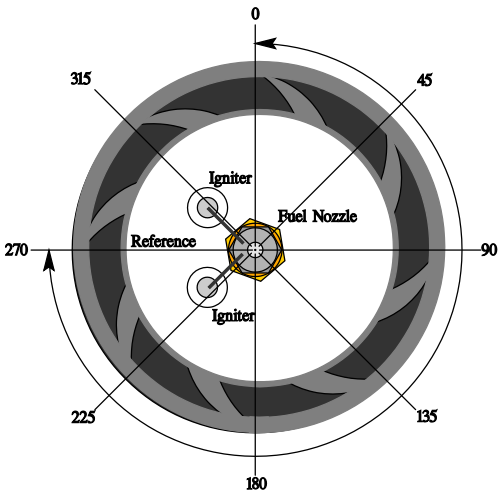
- **Delavan fuel nozzles selected for their uniform spray patterns as well as the measured fuel flow remaining consistent with the rated flow**

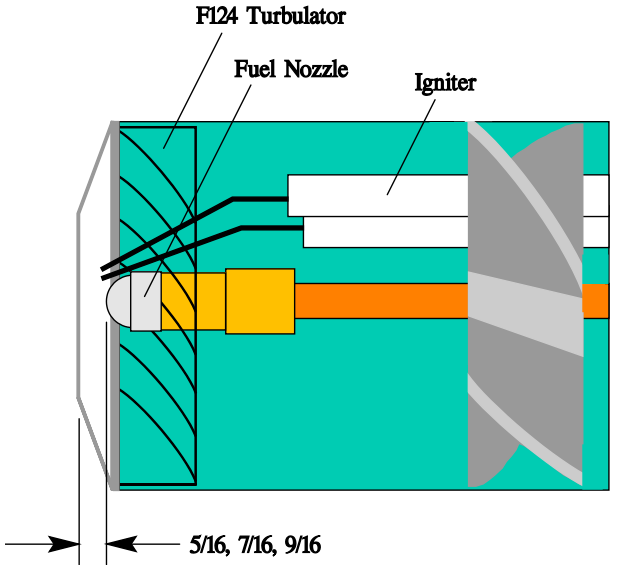




Refining Sonic Burner Settings





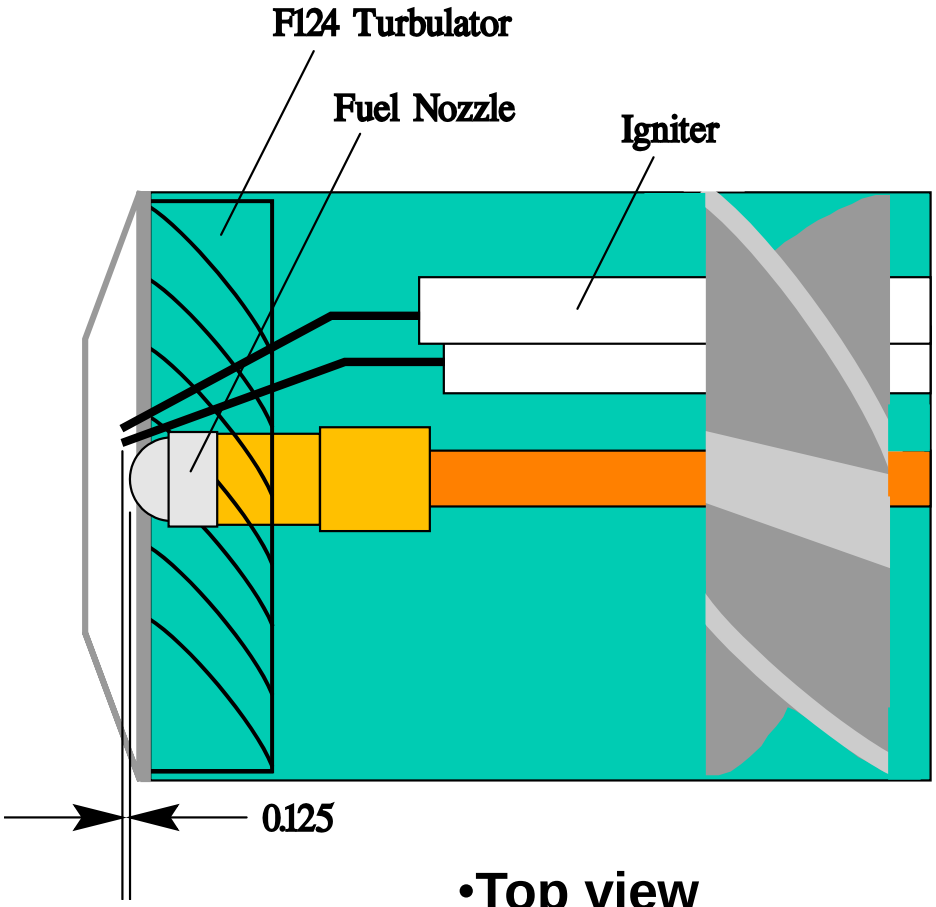


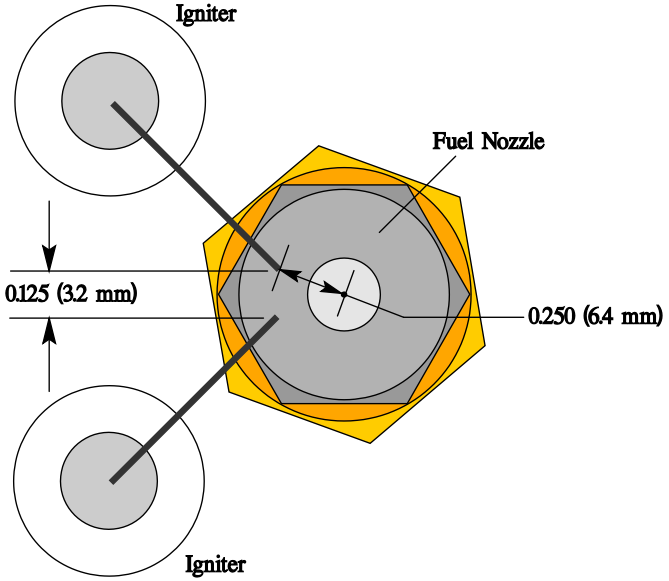
3 Stator Positions X 8 Stator Angles X 3 Nozzle Depths

= 72 Combinations

= LOTS OF DATA

Example: Igniter Positions





•Top view

(side facing sample wall on test rig)

•Front view

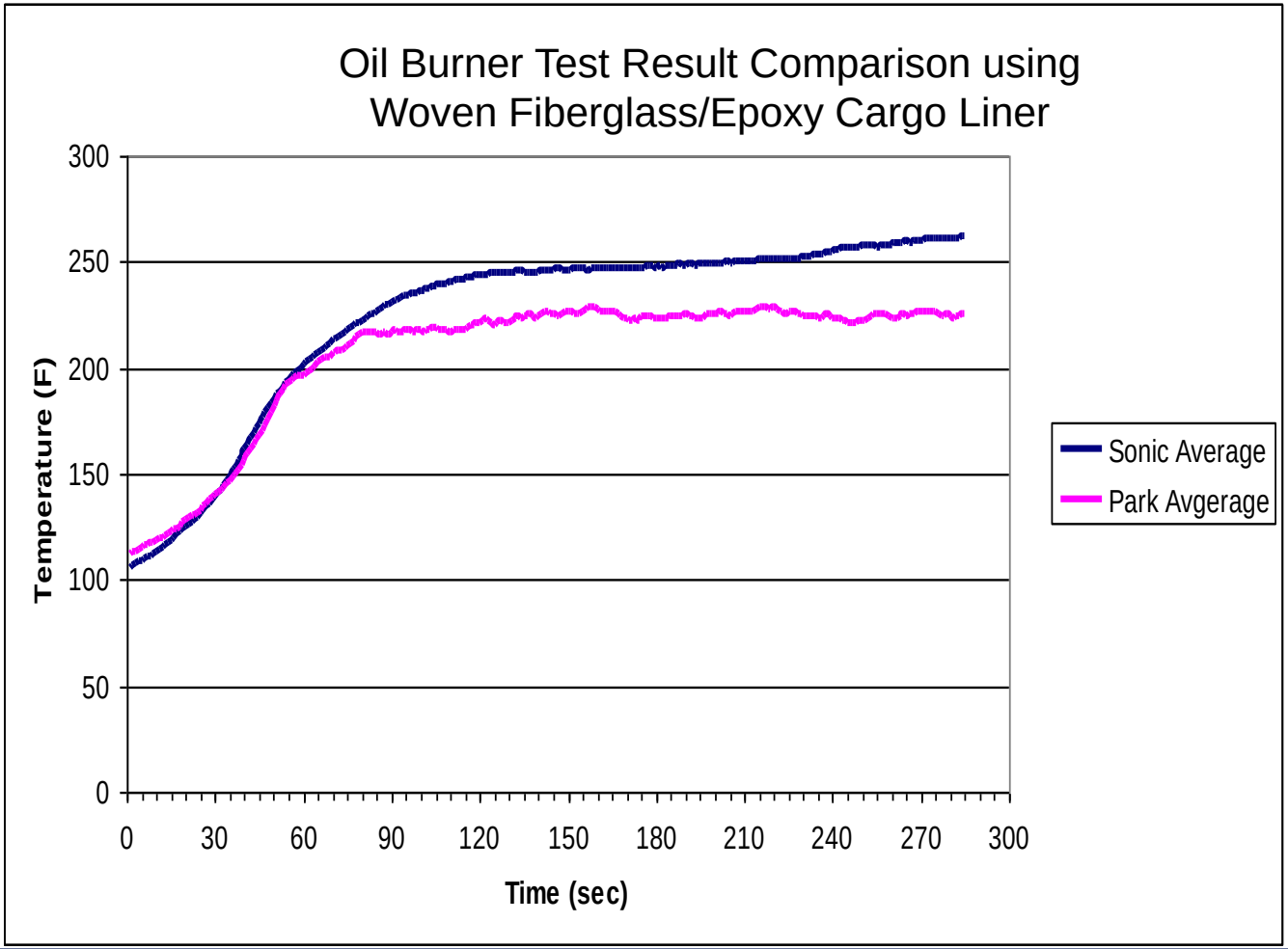
(looking into cone)

Example: Cargo Sonic Burner Settings

- **Sonic burner settings for use as Park burner replacement**
  - All depths are measured from the exit plane of the turbulator to the nozzle tip or front stator face
  - **Recommended Nozzle:** Delevan 2.0 gal/hr type B
  - **Nozzle Depth:** 9/16”
  - **Stator Depth:** 3 5/16”
  - **Stator Angle:** 270° (centerline from vertical)
  - **Turbulator Angle:** Notch will face bottom of tube (180°)
  - **Air Pressure:** 47.5 psi
  - **Air Temperature:** 40-60°F
  - **Fuel Temperature:** 32-52°F

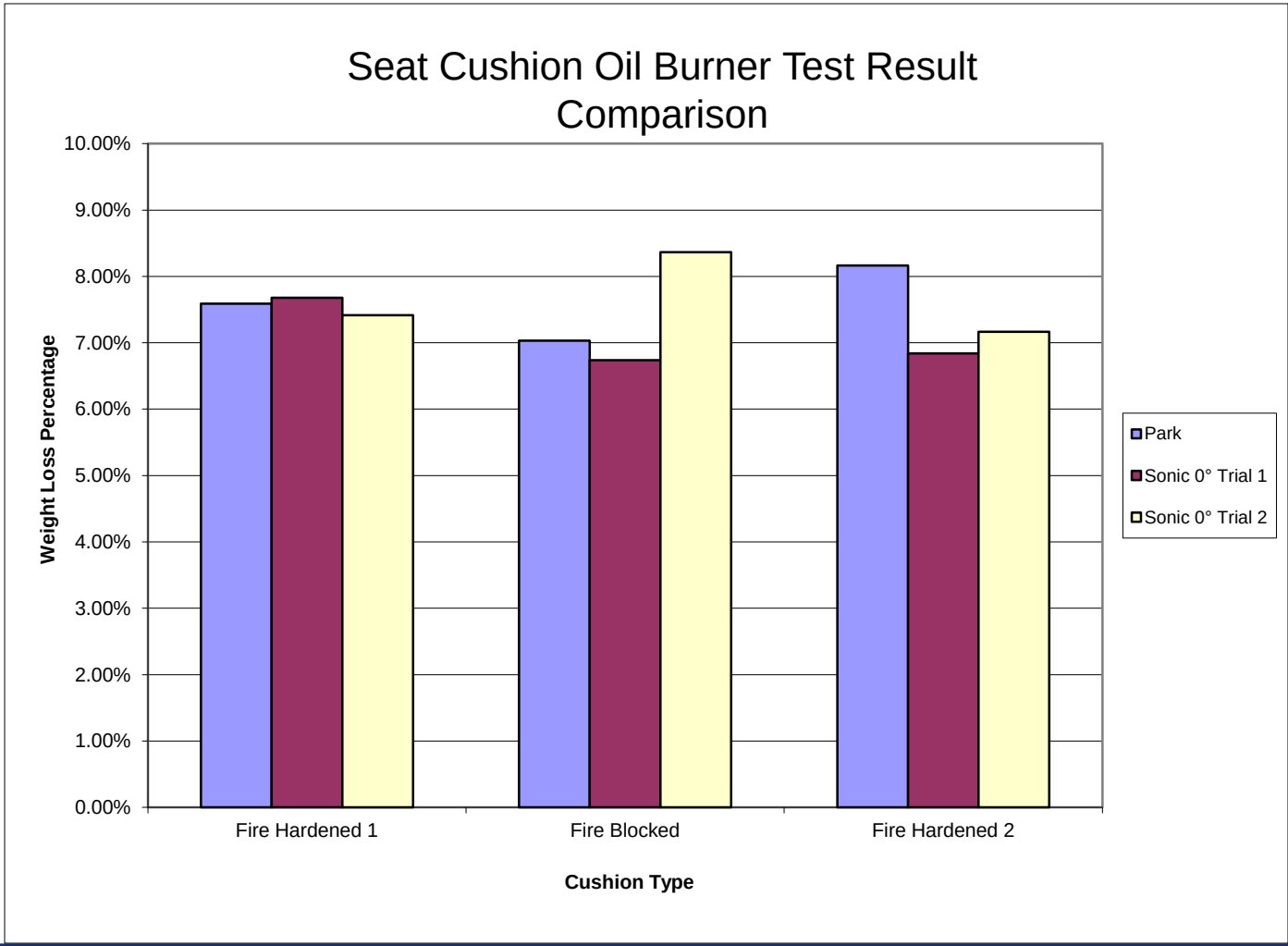
FAA Park Vs. NexGen Burner Cargo Liner Test Result Comparison

- **6 test sample types**
  - 2 different epoxy coated woven fiberglass liners
  - 1 Kevlar liner
  - 1 PAN felt material
  - 2 additional materials



FAA Park Vs. NexGen Burner Seat Cushion Test Result Comparison

- **3 cushion types**
  - 2 different fire hardened foams
  - 1 fire blocked foam
- **All cushions covered in the same fabric**



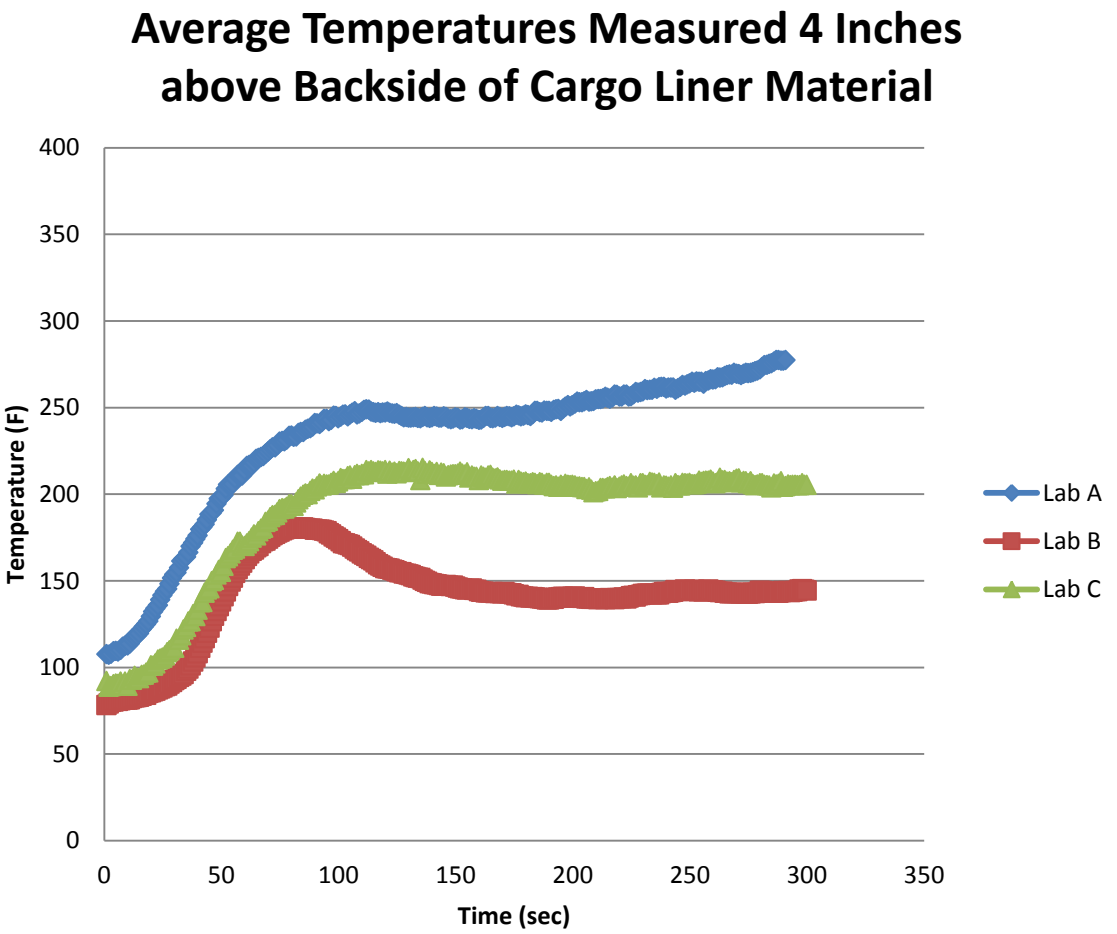
Round Robin Testing

- **Once testing has been completed at the FAA test facility, and the proper settings for the NexGen burner have been determined, the next step is to organize a round robin…**

- **What is a round robin?**
  - A round robin is an interlab study where participating flammability test facilities are all provided with identical test specimens and required to run a particular flammability test in a manner specified by the FAA. All test equipment as well as test procedures between labs are designed to be as equal as possible.

NexGen Cargo Round Robin Results

- **5 heavy cargo liner samples**
  - Sample tested for 5 minutes
  - Measure temperature 4 inches above sample material during 5 minute test period (data shown in graph)
- **5 light cargo liner samples**
  - Sample tested for 5 minutes
  - Measure temperature 4 inches above sample material during 5 minute test period (data shown in graph)
- **5 PAN felt samples**
  - Test sample until flame visibly penetrates through material
  - Use stopwatch to determine time to burn through



NexGen Cargo Round Robin Results

- **Measured time to burn through for PAN felt material was relatively consistent and similar among labs**
- **Percent standard deviation is within the acceptable limit of 10% for all labs**
- **Burnthrough times are encouraging, however, the spread of temperatures among participating labs measured during cargo liner testing was larger than expected**

	Lab A	Lab B	Lab C
	Time (sec)	Time (sec)	Time (sec)
	393	334	387
	351	363	353
	386	380	342
	378	403	
	342	408	
avg	370	378	361
stdev	22.33	30.37	23.46
%stdev	**6.03**	**8.04**	**6.50**

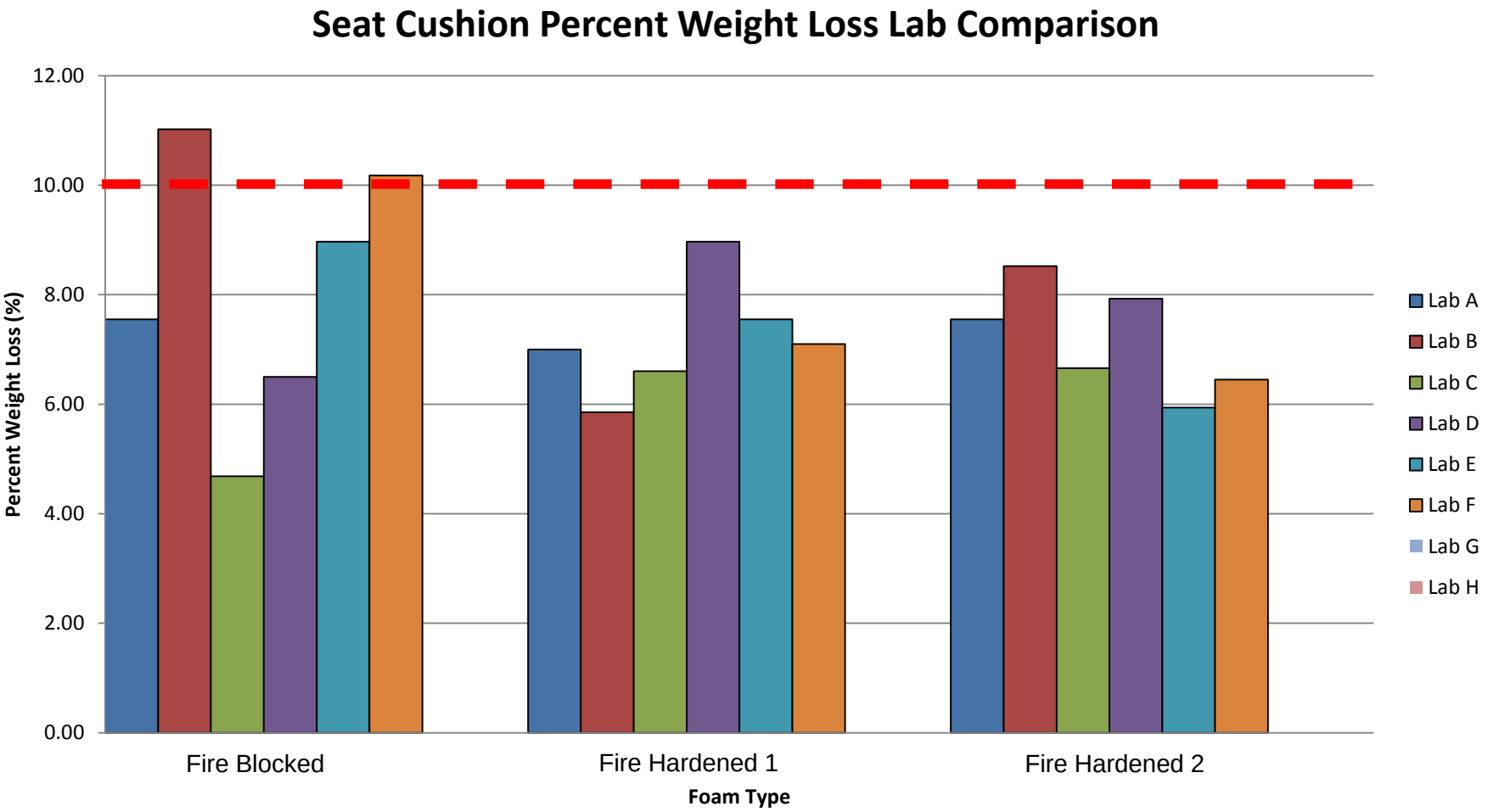
NexGen Seat Cushion Round Robin Results

- **Fire blocked foam**
  - 3 test specimens
- **Fire hardened foam 1**
  - 3 test specimens
- **Fire hardened foam**
  - 3 test specimens
- **All test specimens are exposed to the NexGen burner flame for a period of 2 minutes**
- **Measure and record weight loss %, as well as burn lengths on four different surfaces of the test specimen**
- **Standard deviation % is above the acceptable limit of 10% for all foam types**

Average Seat Cushion Weight Loss % Among Labs

	FB	FH1	FH2
Lab A	7.55	7.00	7.55
Lab B	**11.02**	5.85	8.52
Lab C	4.69	6.60	6.66
Lab D	6.50	8.97	7.93
Lab E	8.97	7.55	5.94
Lab F	**10.18**	7.10	6.45
Lab G			
Lab H			
Avg	8.15	7.18	7.17
stdev	2.37	1.05	0.98
%stdev	**29.09**	**14.57**	**13.72**

NexGen Seat Cushion Round Robin Results



Conclusions

- **The NexGen burner was developed in FAA test facilities, and demonstrated to be capable of satisfactorily reproducing Park burner test results in FAA test labs**

- **The conducted interlab studies proved there to be some difficulty in obtaining repeatable results with the proposed configuration of the NexGen burner**

- **New ideas and burner configurations would continued to be researched in order to improve upon the test result repeatability of the NexGen burner**

Questions?