The Seventh Triennial International Fire & Cabin Safety Research Conference

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

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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
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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

Cone
Fuel Nozzle
Turbulator
Igniters
Draft Tube
Stator
Housing
Muffler
Pressure Regulator
Sonic Orifice
Cradle
Thermal/Acoustic Insulation Burnthrough

Cargo Liner Burnthrough

Seat Cushion Flammability
Burner Control

Air Flow

Fuel Flow

Regulated and conditioned air and fuel to burner

\[ m = 0.89 \times P_i + 12.43 \]
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.
Main Objective: Transition from Park Burner to Sonic Burner
Burner Transition Plan for Cargo Liner and Seat Cushion Flammability Tests

Park Burner Testing
- Generate calibration and test data using Park burner

Sonic Burner Assembly
- Construct sonic burner apparatus and sample test rig

Sonic Calibration and Testing
- Collect calibration and test data using multiple sample types

Sonic Burner Adjustment
- Make necessary adjustments to sonic burner such that it will replicate Park burner results

Repeat Sonic Calibration and Testing
- Repeat calibration and testing following adjustments to ensure results match that of the Park burner

Sonic Burner Round Robin
- Conduct interlab study using sonic burner and multiple sample types

Analyze Test Results
- Review test results form interlab study, and make adjustments to sonic burner if necessary
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
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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

![Seat Cushion Oil Burner Test Result Comparison](chart)

<table>
<thead>
<tr>
<th>Cushion Type</th>
<th>Weight Loss Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire Hardened 1</td>
<td>7.00%</td>
</tr>
<tr>
<td>Fire Blocked</td>
<td>8.00%</td>
</tr>
<tr>
<td>Fire Hardened 2</td>
<td>8.00%</td>
</tr>
</tbody>
</table>

- Park
- Sonic 0° Trial 1
- Sonic 0° Trial 2
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

**Average Temperatures Measured 4 Inches above Backside of Cargo Liner Material**

- Lab A
- Lab B
- Lab C
NexGen Cargo Round Robin Results

- Measured time to burn through for PAN felt material was relatively consistent and similar among labs.

<table>
<thead>
<tr>
<th></th>
<th>Lab A</th>
<th>Lab B</th>
<th>Lab C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (sec)</td>
<td>393</td>
<td>334</td>
<td>387</td>
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<tr>
<td>Time (sec)</td>
<td>351</td>
<td>363</td>
<td>353</td>
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<tr>
<td>Time (sec)</td>
<td>386</td>
<td>380</td>
<td>342</td>
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<td>Time (sec)</td>
<td>378</td>
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</tr>
<tr>
<td>Time (sec)</td>
<td>342</td>
<td>408</td>
<td></td>
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</table>

- 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.

<table>
<thead>
<tr>
<th></th>
<th>Lab A</th>
<th>Lab B</th>
<th>Lab C</th>
</tr>
</thead>
<tbody>
<tr>
<td>avg</td>
<td>370</td>
<td>378</td>
<td>361</td>
</tr>
<tr>
<td>stdev</td>
<td>22.33</td>
<td>30.37</td>
<td>23.46</td>
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<tr>
<td>%stdev</td>
<td>6.03</td>
<td>8.04</td>
<td>6.50</td>
</tr>
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</table>
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

<table>
<thead>
<tr>
<th></th>
<th>FB</th>
<th>FH1</th>
<th>FH2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab A</td>
<td>7.55</td>
<td>7.00</td>
<td>7.55</td>
</tr>
<tr>
<td>Lab B</td>
<td>11.02</td>
<td>5.85</td>
<td>8.52</td>
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<tr>
<td>Lab C</td>
<td>4.69</td>
<td>6.60</td>
<td>6.66</td>
</tr>
<tr>
<td>Lab D</td>
<td>6.50</td>
<td>8.97</td>
<td>7.93</td>
</tr>
<tr>
<td>Lab E</td>
<td>8.97</td>
<td>7.55</td>
<td>5.94</td>
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<tr>
<td>Lab F</td>
<td>10.18</td>
<td>7.10</td>
<td>6.45</td>
</tr>
<tr>
<td>Lab G</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lab H</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avg</td>
<td>8.15</td>
<td>7.18</td>
<td>7.17</td>
</tr>
<tr>
<td>stdev</td>
<td>2.37</td>
<td>1.05</td>
<td>0.98</td>
</tr>
<tr>
<td>%stdev</td>
<td>29.09</td>
<td>14.57</td>
<td>13.72</td>
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</tbody>
</table>
NexGen Seat Cushion Round Robin Results

Seat Cushion Percent Weight Loss Lab Comparison

- Fire Blocked
- Fire Hardened 1
- Fire Hardened 2

Foam Type

Percent Weight Loss (%)

Lab Comparison:
- Lab A
- Lab B
- Lab C
- Lab D
- Lab E
- Lab F
- Lab G
- Lab H

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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?