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2024 ATF PERFORATING GUN TEST SERIES TO SUPPORT QUANTITATIVE RISK ASSESSMENTS

2025 International Explosives Safety Summit and Exposition (IESSE)
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OUTLINE

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- How Does IMESAFR Model JPGs?
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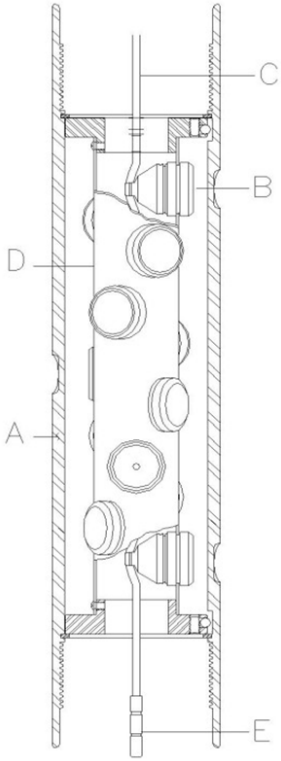
WHAT IS A JET PERFORATING GUN?

- Jet Perforating Guns (JPGs) are specialized tools used in the oil and gas industry
- JPGs are used to assist in the completion of wells
- Contain conical shaped charges that produce hypervelocity jets that punch through the gun body, the wellbore, and the surrounding rock
- Designed to operate in high-pressure-fluid environments

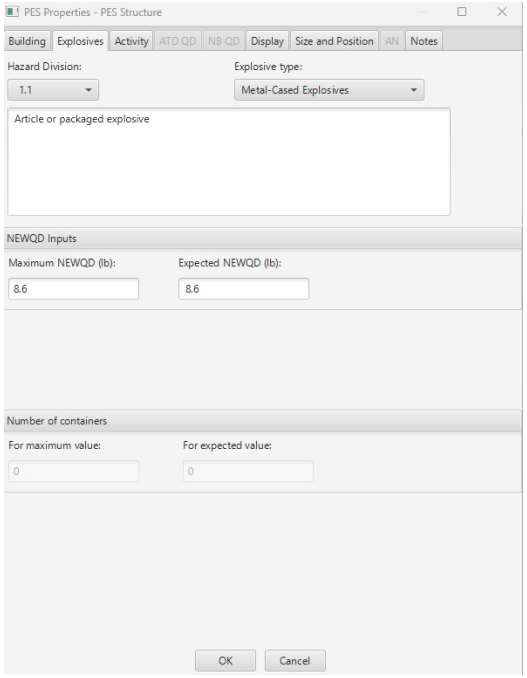


Gun System Components

Label	Component	Comments
A	Gun body	
B	Perforator	
C	Detonating Cord	
D	Carrier Tube	
E	Explosive Transfer Device (explosive) or Detcord End Seal (non-explosive)	Optional Optional
F	Lead Wire	Optional (not shown)

HOW DOES IMESAFR MODEL JPGS?

- Institute of Makers of Explosives (IME) Safety Assessment for Risk (IMESAFR©) has a preexisting model for JPGs
- This original model was based on data extrapolated from a model of a larger surrogate explosive article
- This surrogate item was not a JPG and was much larger than modern versions of JPGs
- Considering the difference in size and net explosives weight (NEW) between the surrogate item and those tested it is unknown how accurately IMESAFR can model modern JPGs
- For more details on IMESAFR see *QRA for Regulatory Application Using IMESAFR*



Explosives Type	NEWQD of one article (lb)	Bin 1	Bin 2	Bin 3	Bin 4	Bin 5	Bin 6	Bin 7	Bin 8	Bin 9	Bin 10
Metal-cased explosives articles	8.6	0	0	0	0	0	0	4	19	44	79

TESTING BACKGROUND

- The Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) sponsored the performance of this test series
  - The ATF is the governmental organization that regulates the storage of commercial explosives in the United States, including the storage JPGs
  - By enhancing IMESAFR's ability to model JPGs, the risk in operations utilizing JPGs can be better predicted and managed, potentially leading to safer scenarios
- The primary objectives of these tests, in order of priority, were to characterize the following parameters upon forced initiation of the JPG(s) in each of the emplacement conditions:
  - Range, bearing, and mass of the fragments produced by the JPG body
  - Pressure as a function of distance
  - Velocity of fragments

TEST MATRIX

After several iterations and consulting with range personnel, JPG subject matter experts, ATF, and IME, this test matrix was agreed to be a good (and achievable) starting point for JPG testing:

Test	JPG	Diameter	Length	Initiation Height	Number of Items	Orientation	NEW per Charge	Total Weight (Gun + Charges)
Test 1	Company A*	3.125 in	23 in	1 ft	Single	Horizontal	21.5 g	10,117 g
Test 2	Company B	3.125 in	21 in	1 ft	Single	Horizontal	21.5 g	9,448 g
Test 3	Company A	3.125 in	23 in	1 ft	Single	Horizontal	21.5 g	9,639 g
Test 4	Company C	3.125 in	24.5 in	1 ft	Single	Horizontal	21.5 g	13,416 g
Test 5	Company B	3.125 in	21 in	3 ft	Single	Horizontal	21.5 g	9,502 g
Test 6	Company D	3.125 in	~ 15 in	1 ft	Single	Horizontal	23 g	10,467.8 g
Test 7	Company B	3.125 in	21 in	Gun on Pallet	Single	Vertical	21.5 g	9,464 g
Test 8	Company B	3.125 in	21 in	Gun on Pallet	Multiple (6)	Horizontal	21.5 g	56,936 g

*For the sake of confidentiality, the companies that donated perforating guns for this test series are referred to as Companies A, B, C, and D throughout this presentation

CREW DESCRIPTION

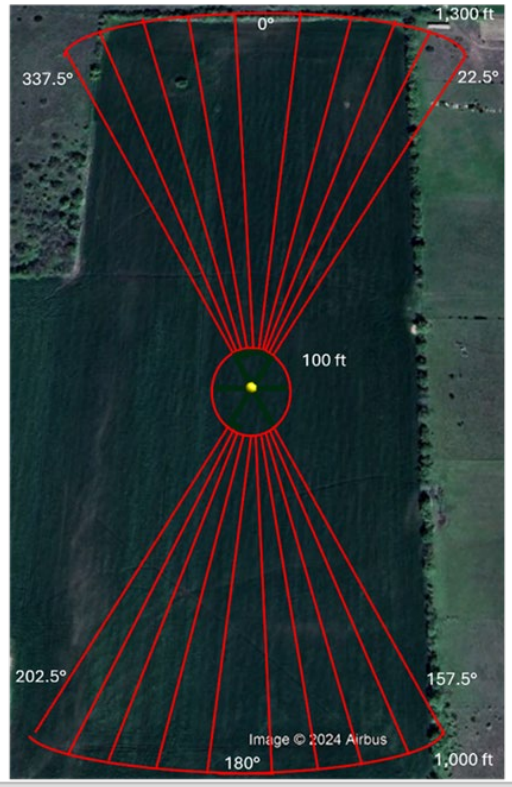
- The total crew size for this test series was approximately 20 people
- The core of the crew was made up of personnel from APT, ATF, IME, and R.A. McClure Inc. (RAM), with members of IME's oil and gas sector present for specific tests
- As the primary groups participating in this test series, APT, ATF, IME, and RAM all had unique responsibilities during this test series
  - APT: test plan, test report, data analysis
  - ATF: Instrumentation plan, camera setup, pressure gauge setup*
  - IME: Support testing and coordinate between the various entities participating
  - RAM: Establish the GPS points for the grid, film drone footage, and record GPS coordinates of all recovered debris

*Note that the analysis of the highspeed/drone footage and pressure gauges is not included in this presentation but is covered in detail in the full paper

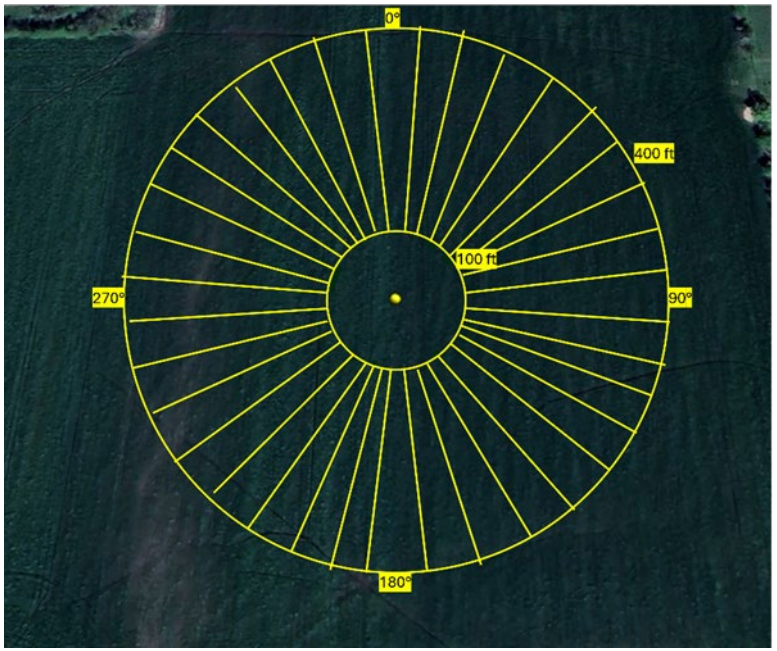
TEST SET UP

- This test series took place in Texas at Company A's private test site
- Testing occurred over the course of three weeks in July/August 2024 and broken down into two phases

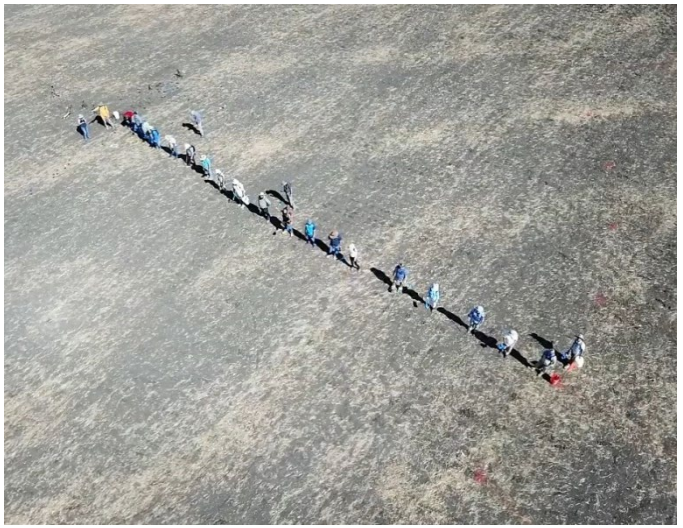
Phase 1 Search Grid



Phase 2 Search Grid

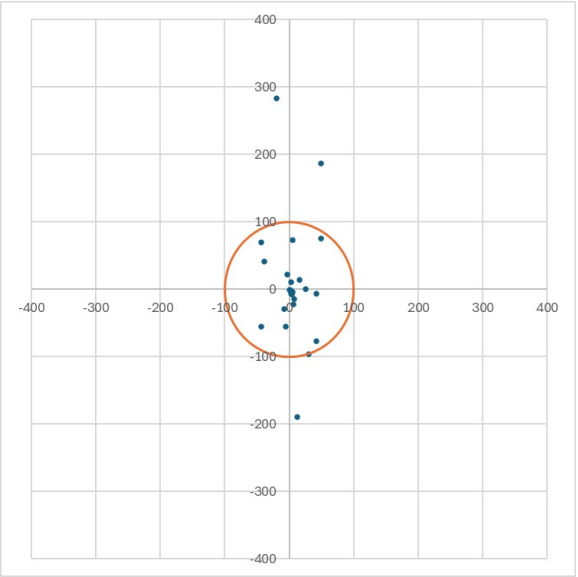


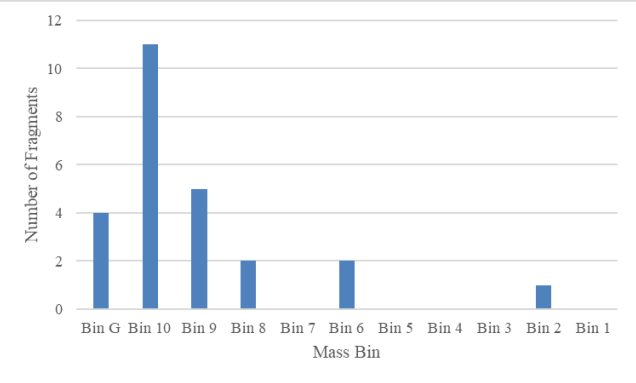
TEST RESULTS



TEST 1 RESULTS

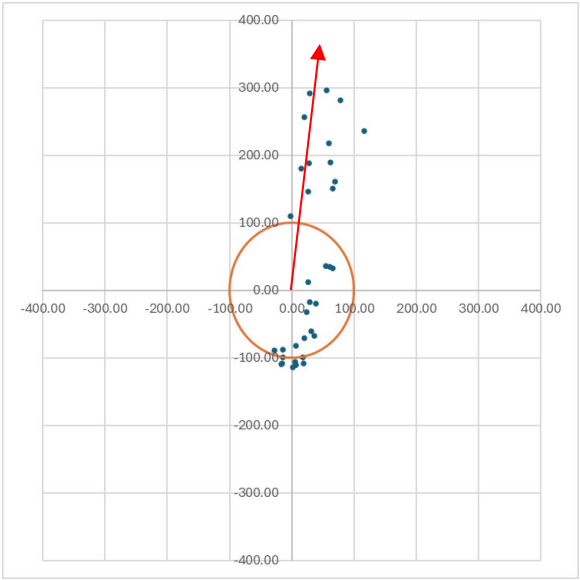
- Test 1 was performed using a JPG from Company A
- JPG was positioned horizontally, 1 foot above ground
- This JPG had a bulkhead installed
  - Was not recovered – exited recovery area
  - Accounted for ~7% of initial mass
- In total, 25 fragments above 5 grams were recovered
- 87.62% of the initial mass was recovered

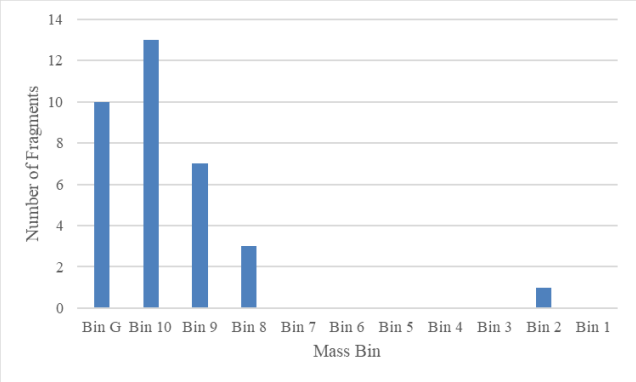




TEST 2 RESULTS

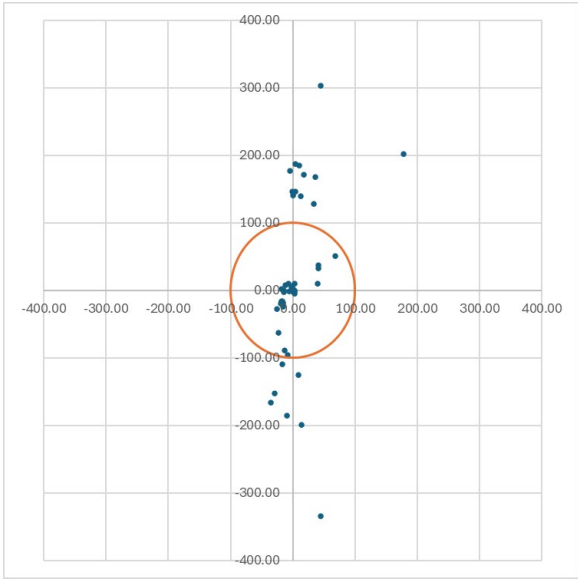
- Test 2 was performed using a JPG from Company B
- JPG was positioned horizontally, 1 foot above ground
- In total, 34 fragments above 5 grams were recovered
- 91.6% of the initial mass was recovered

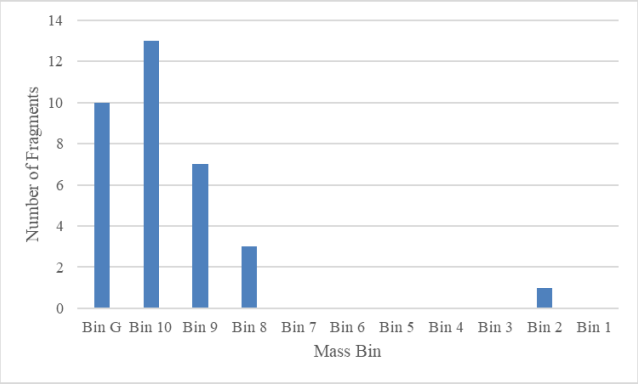




TEST 3 RESULTS

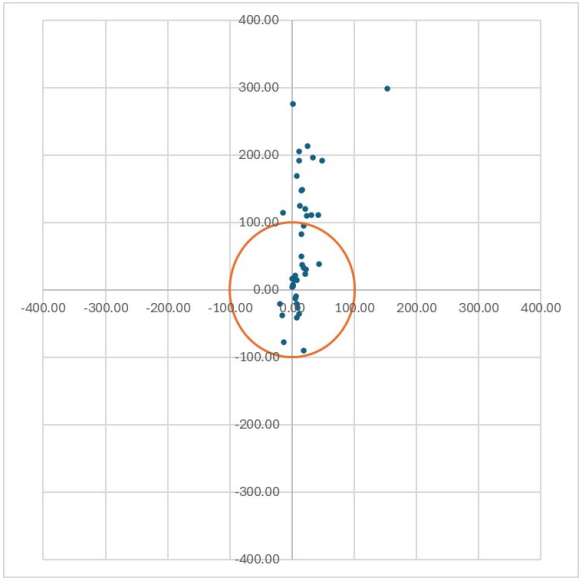
- Test 3 was performed using a JPG from Company A
- This Company A JPG did NOT have a bulkhead installed
- JPG was positioned horizontally, 1 foot above ground
- In total, 51 fragments above 5 grams were recovered
- 95.4% of the initial mass was recovered

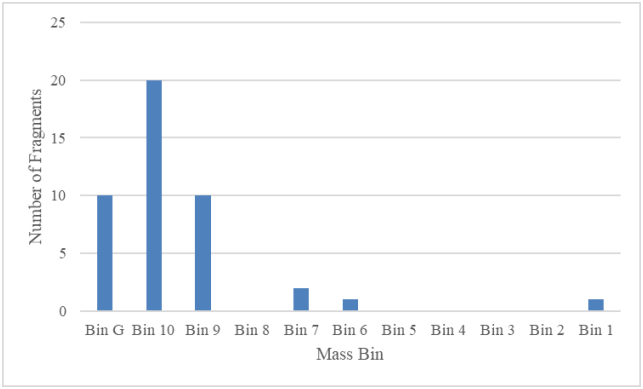




TEST 4 RESULTS

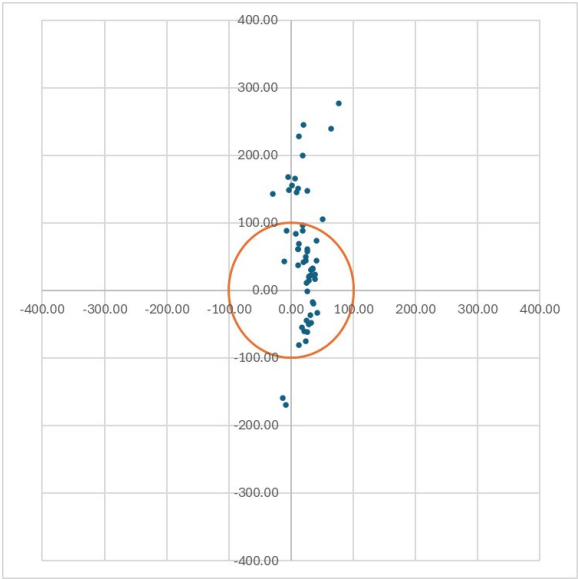
- Test 4 was performed using a JPG from Company C
- JPG was positioned horizontally, 1 foot above ground
- In total, 44 fragments above 5 grams were recovered
- 95.7% of the initial mass was recovered

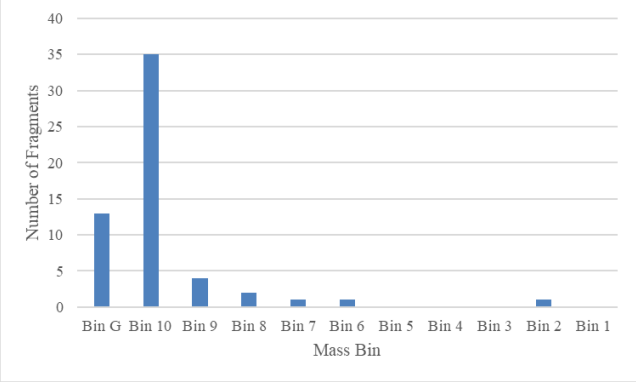




TEST 5 RESULTS

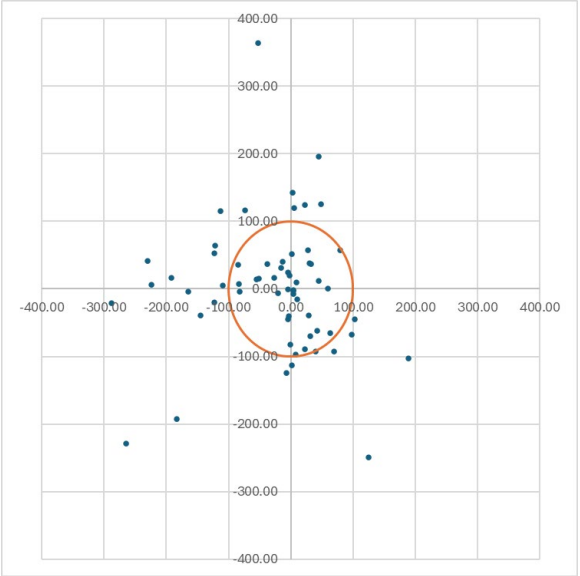
- Test 5 was performed using a JPG from Company B
- JPG was positioned horizontally, 3 feet above ground
- In total, 57 fragments above 5 grams were recovered
- 95.6% of the initial mass was recovered

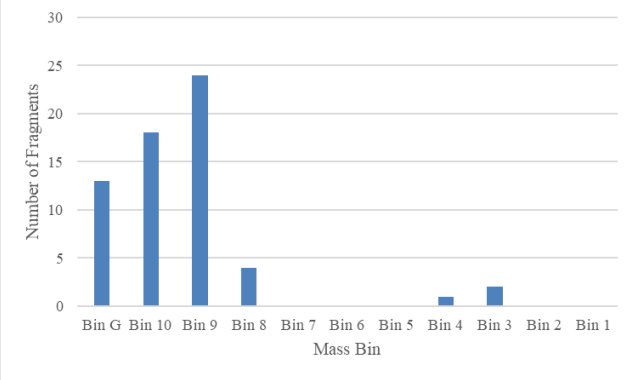




TEST 6 RESULTS

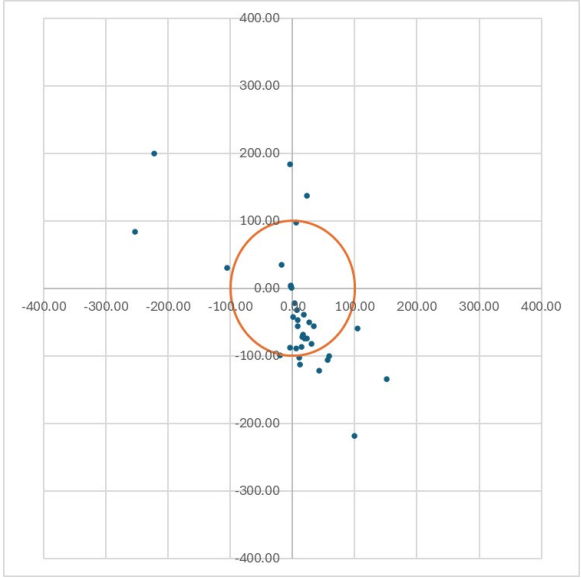
- Test 6 was performed using a JPG from Company D
- JPG was positioned horizontally, 1 foot above ground
- This JPG had a higher NEW per charge than the others tested
- In total, 62 fragments above 5 grams were recovered
- 96.8% of the initial mass was recovered

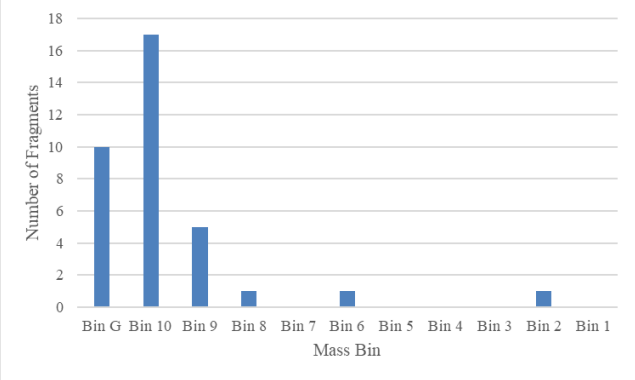




TEST 7 RESULTS

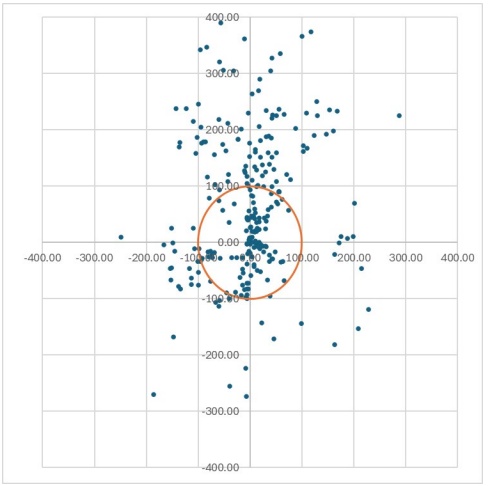
- Test 7 was performed using a JPG from Company B
- JPG was positioned vertically on top of a pallet
- In total, 35 fragments above 5 grams were recovered
- 96.3% of the initial mass was recovered

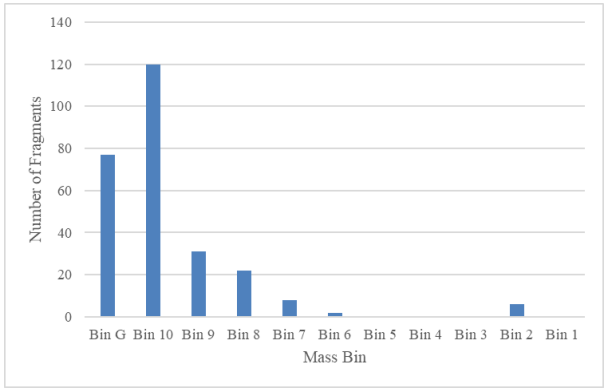


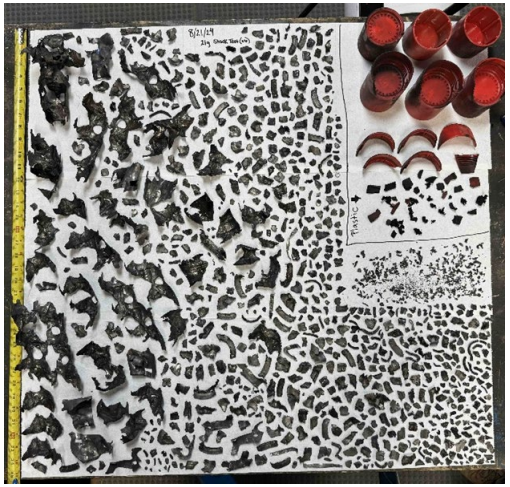


TEST 8 RESULTS

- Test 8 was performed using a JPG from Company B
- This test utilized six JPGs in 3-2-1 stack
- JPGs were placed on a pallet
- In total, 266 fragments above 5 grams were recovered
- 94% of the initial mass was recovered





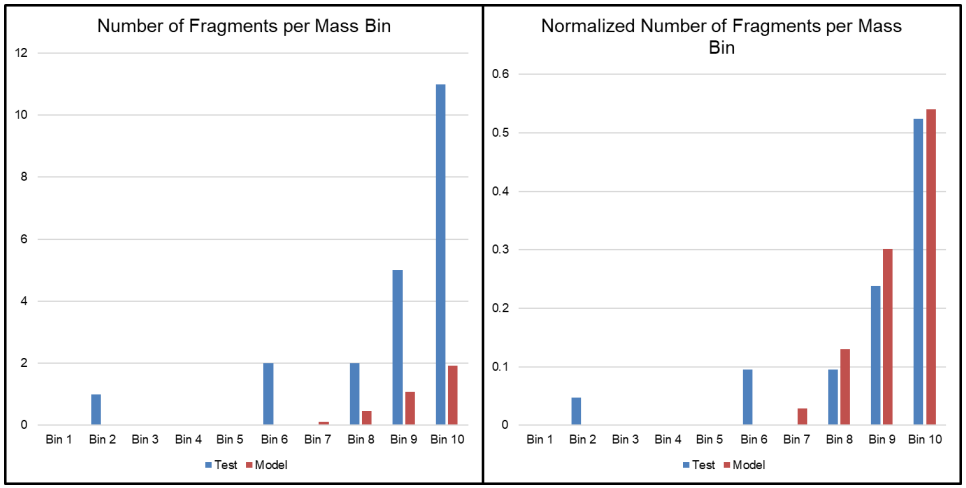


MODEL COMPARISON

- In order to determine the accuracy of the existing JPG model, some comparison had to be made between the test data and IMESAFR's predictions
- For every test the following was compared:
  - Max throw distance
  - Number of fragments per mass bin
  - Debris density within specific bands
- Comparison results indicate that IMESAFR is conservative in some aspects, but underpredicts other elements of the JPG behavior

Example of comparisons made using Test 1 data

Density	0 – 100 ft	100 – 200 ft	200 – 300 ft	300 – 400 ft	1,300 – 1,400 ft (Bulkhead)
Test	9.14E-05	5.38E-06	1.08E-06	0	1.67E-07
Model	3.08E-07	6.94E-07	1.25E-06	1.79E-06	8.51E-07



FUTURE PLANS

- Due to time, funding, and range constraints not all of the desired tests could be completed at the time of this test series
- Therefore, further JPG testing will be necessary in the future
- Some parameters that specifically need to be tested include:
  - Different JPG sizes
  - Phasing angle
  - Total number of charges
  - Number of charges per foot
- Additional testing is also desired so that the behavior of installed bulkheads can be fully captured

SUMMARY AND CONCLUSIONS

- The primary goal of this test series was to collect empirical test data that could be used to improve IMESAFR's JPG model
- Originally it was unknown exactly how accurate the current model was
- Upon comparing the results of the tests to IMESAFR it was found that the model was conservative in some areas and unconservative in others
  - IMESAFR is predicting debris traveling farther than what was observed in testing
  - IMESAFR is underpredicting the number of fragments
- Overall, this test series has provided a significant amount of data that can be used to begin the process of improving the model
- However, there are still additional parameter to be tested

Questions?