IMESAFR - QRA Tool
Perforating Gun Safety Analysis

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Figure 1-2. The tremendous power of an oilwell perforator demonstrated by a perforating gun detonated at the surface. The figure at left is a mannequin.

PERFORATORS.ORG
INTERNATIONAL PERFORATING FORUM

2016 International Perforating Symposium
May 9-11 - Galveston, Texas

Who is the Institute of Makers of Explosives?

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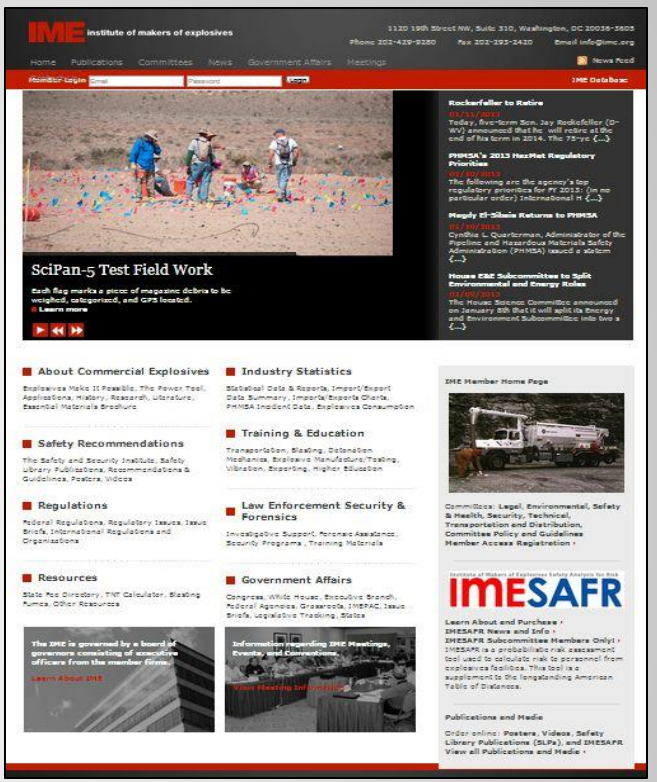
- **Safety and Security Association for the Commercial (Industrial) Explosives Industry in the US and Canada Since 1913**
- **Develops Recommended Practices**
- **Provides Information to Legislators, Regulators and Law Enforcement**
- ***<u>One of IME's Original Tasks was to Create the American Table of Distances (ATD)</u>***



Posters

Reference Materials

Safety Library Publications

Videos

Member Companies

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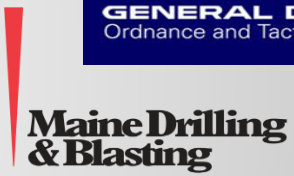

, IME membership consists of 40 companies which manufacture over 95% of the commercial products consumed throughout the United States.

203 Committee Participants **7 Permanent Staff**

Safety Library Publications - SLP

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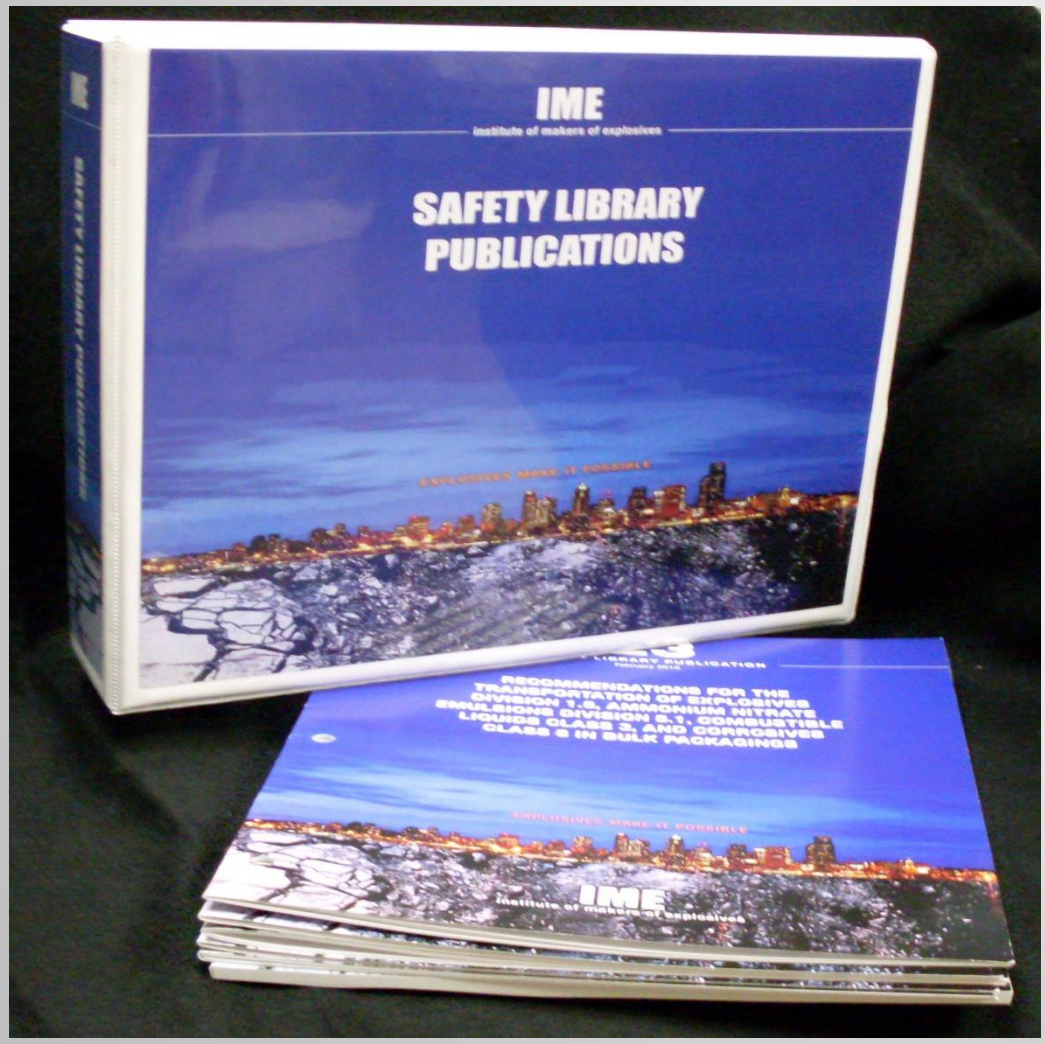

- SLP Library
  - Free at ime.org
- Updated Often
  - 4-5 New Updates
- 3 New SLPs Under Development
  - AN (NH4NO3)
  - Security
  - Oil & Gas

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IMESAFR – A Tool For Industrial Explosives Risk Management

2016 International Perforating Gun Forum

IME/APT Partnership

The IME recognized improvements possible to explosives risk management offered by the US Department of Defense (DoD) sponsored quantitative risk assessment (QRA) methodologies and algorithms incorporated into the SAFER (Safety Assessment For Explosives Risk) software tool. This work has been overseen by the Risk Based Explosives Safety Criteria Team (RBESCT), which is composed of the DoD Explosive Safety Board (DDESB) and the representatives of the four Services.

APT has supported the RBESCT since 1997 and serves as the software developers of SAFER.

SAFER

First released in 1998

APT is an employee-owned company, headquartered in Huntsville, AL, specializing in providing safety services.

APT has supported the IME since 2005 and serves as the software developers of IMESAFR.

Institute of Makers of Explosives Safety Analysis for Risk
IMESAFR

First released in 2007

What is a Quantitative Risk Assessment Model?

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- **What is a QRA model?**
  - **A quantitative risk assessment model generates numerical values for risk by considering all pertinent elements of the scenario.**
  - **Risk = Probability of the Event (P_e) x Consequence ($P_{f|e}$) x Exposure (E)**
- **Have QRA software tools been developed?**
  - **In the US, the Department of Defense has been developing SAFER. A new software tool, IMESAFR, has been created for the commercial explosives industry.**
- **What is the relationship between SAFER and IMESAFR?**
  - **The programs are independent of each other, but the sponsors maintain communication and share lessons learned.**
- **What is the basis of the method used to calculate the risk?**
  - **The IMESAFR tool is based on semi-empirical models. The availability of applicable test data is a key component of such models. Without enough supporting data, the models must trend towards conservatism.**

Why Were QRA Tools Developed?

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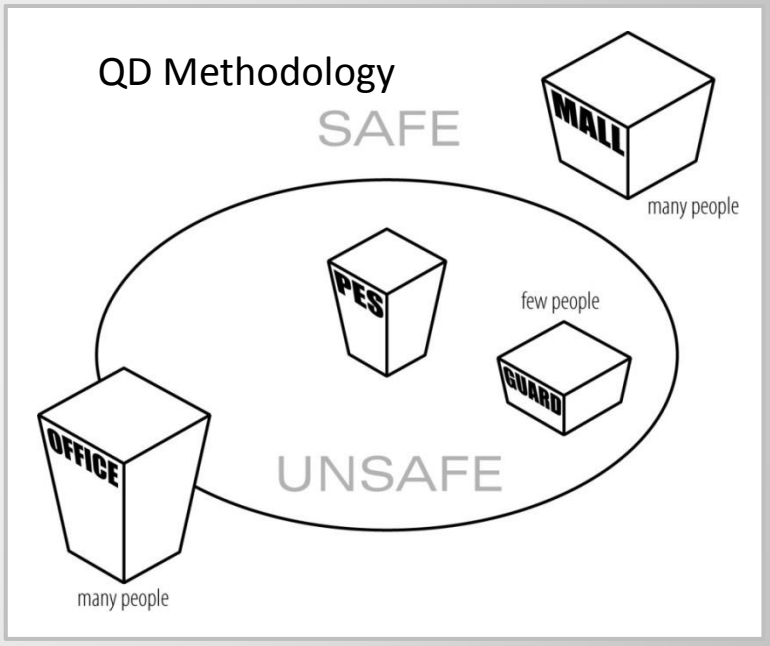
- **Why was SAFER developed?**
  - **The U.S. currently uses Quantity-Distance (QD) criteria as the basis for siting explosives facilities. The QD method only considers explosives quantity, Hazard Division, and PES type to determine a safe separation distance. The SAFER tool was developed to assess risks using additional considerations such as the type of activity at the potential explosion site (PES), the number of people at the exposed site (ES), the building construction of the ES, and assessing the overall risk of an explosives operation.**



What is IMESAFR?

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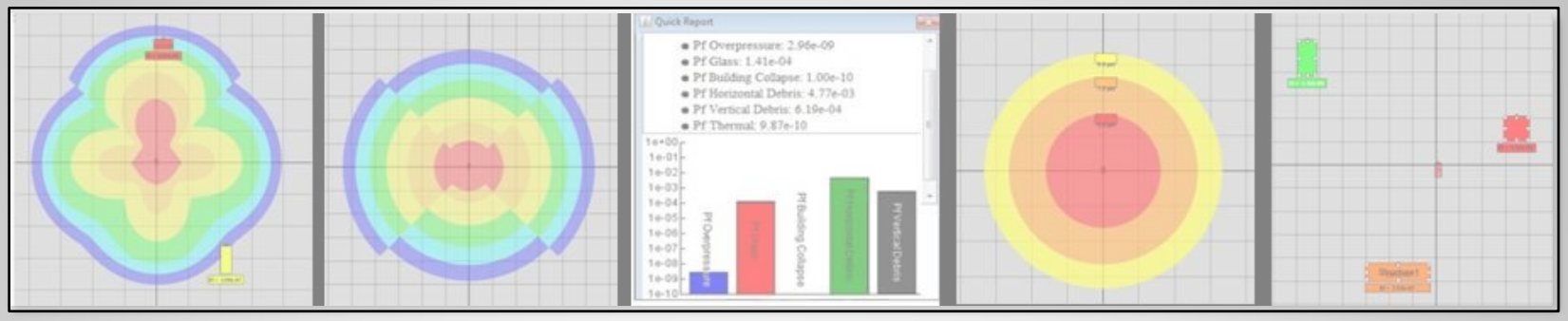
- **IME Safety Analysis for Risk (IMESAFR) is a software tool that was developed through a joint effort by the Institute of Makers of Explosives and APT Research.**



- **IMESAFR is a probabilistic risk assessment tool used to calculate risk to personnel from explosives facilities. This software not only calculates Quantity Distances based on the American Table of Distances (ATD) and other QD regulations, it can determine a level of safety based upon risk.**

- **IMESAFR uses the donor structure and activity, the structure of the exposed sites, and duration of exposed personnel to determine a level of safety. The program provides users with the ability to work in metric or Imperial measures and allows users to import maps or drawings of their site to assist with visualizing facility layouts and results.**

Validation Testing - Critical

What Type of validation testing is conducted to validate IMESAFR?

- **Sensitivity testing**
  - **100s of thousand computer runs are conducted looking for abnormalities**
  - **Additional scenarios are tested by volunteers within the development team**
- **Validation Testing**
  - **Large scale and small scale testing needed to check the predicted distances**
  - **Debris Recovery and Analysis**

Debris Collection Plot for Previous Test

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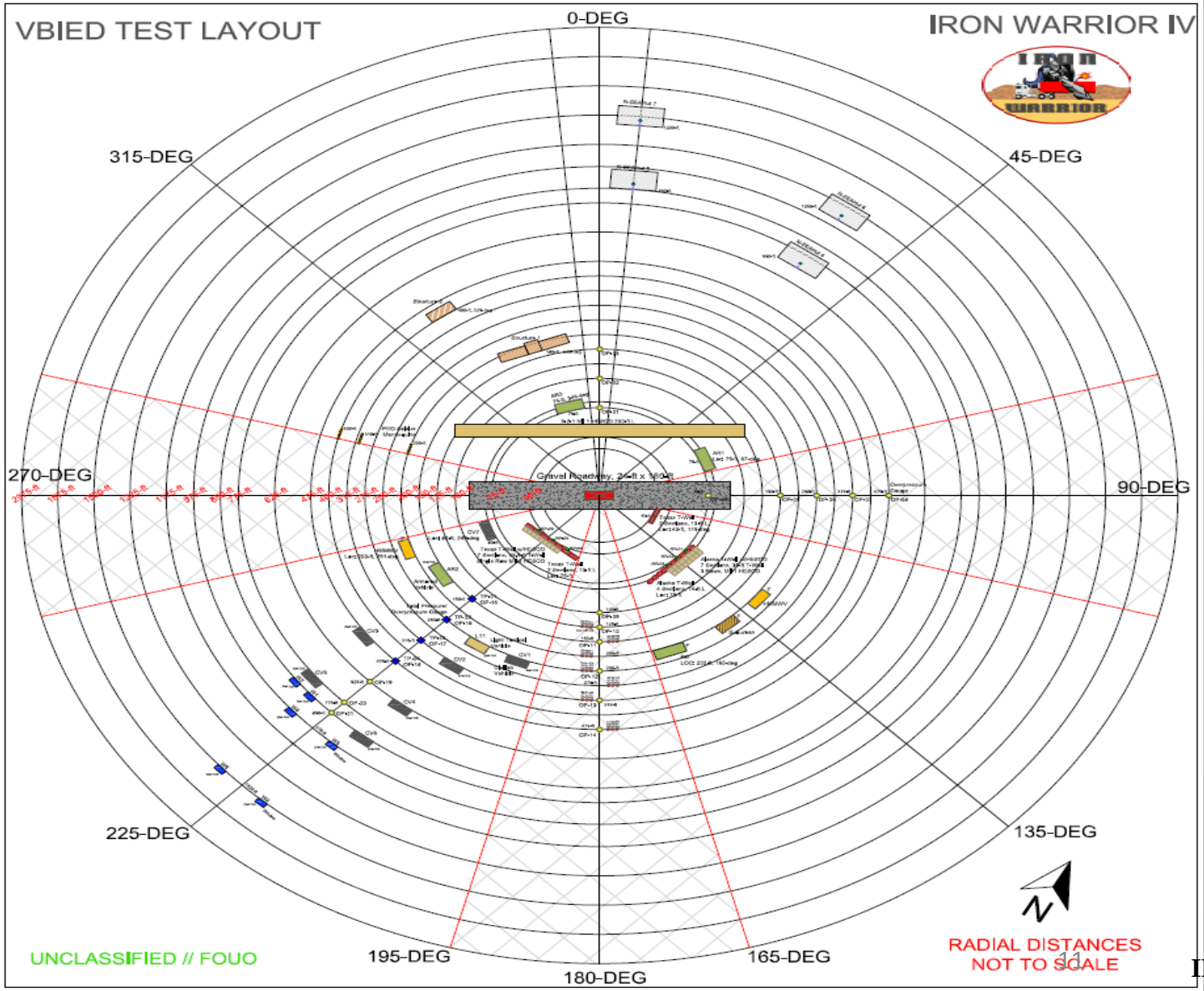
One Experiment Layout



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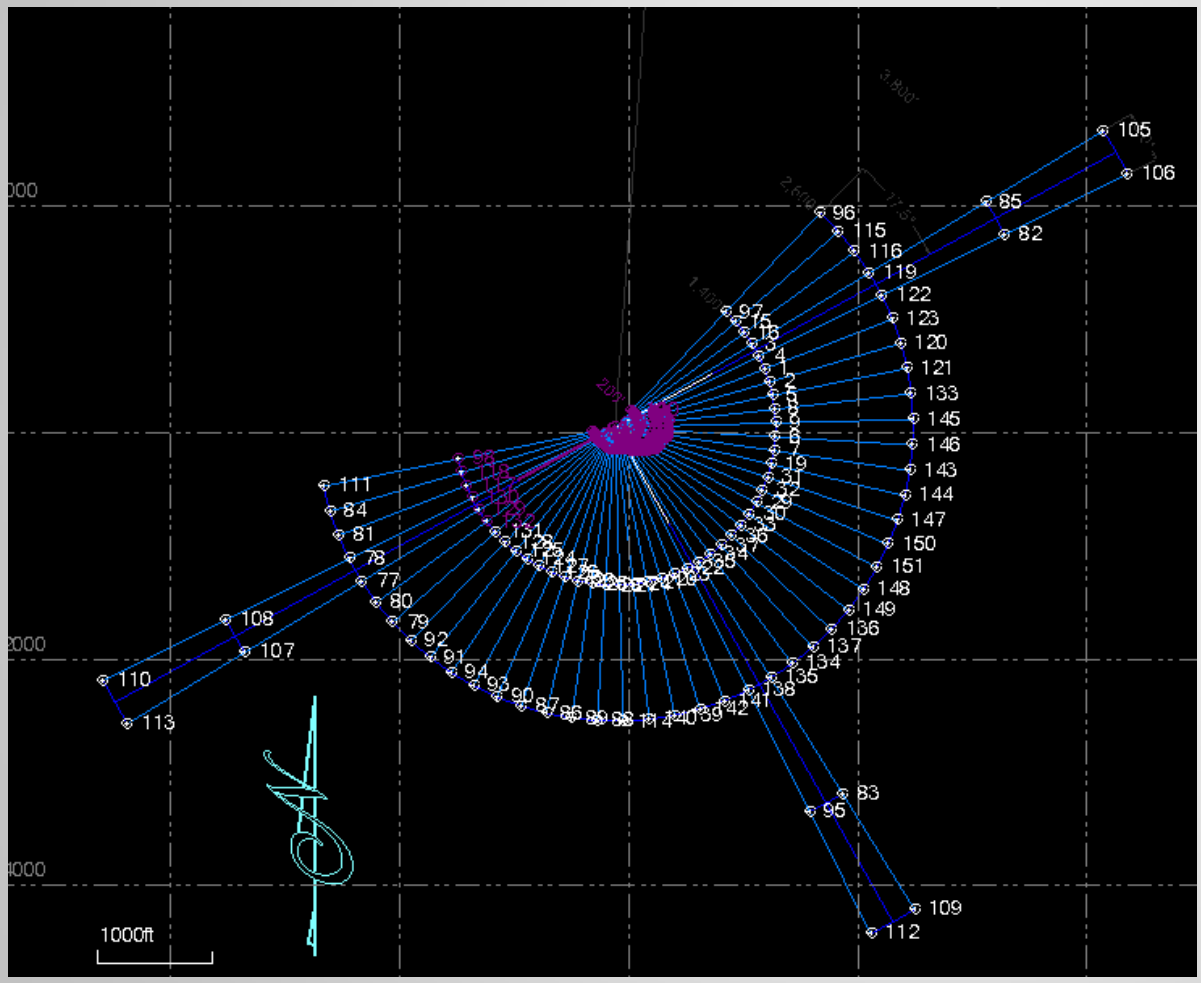
Debris Recovery Effort



- Stakes at every 5 degrees
  - Inner ring is at 200ft
  - Rings at 1,400ft and 2,600ft
- Stakes at 3,800ft and 5,000ft only on the normals
- 215 total degrees covered

Debris Recovery Effort

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- **Total Number of Participants: 48**
- **Total Man-hours worked: 1,944**
- **Man-hours by organization:**
  - **ATF: 744**
  - **IME (including students): 592**
  - **Dyno: 176**
  - **APT: 168**
  - **USATCES: 168**
  - **NAVFAC EXWC: 24**
  - **DDESB: 16**
  - **Orica: 16**

Results

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- ~12,600 points logged
- Efficiency, post-test only: 6.5 points logged per man-hour
- Farthest fragment: approx. 4,300ft (predicted 95% confidence value was 4,200ft)
- About 75% of the fragments were within the 1,400ft ring
- Around 5 fragments were found outside of 2,600ft
- ATD value is 2,000ft

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Perforating Gun Test

Figure 1-2. The tremendous power of an oilwell perforator demonstrated by a perforating gun detonated at the surface. The figure at left is a mannequin.

Why are these tests Being Conducted?

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- **The IME Oilfield Services Subcommittee requested testing be conducted on both horizontally and vertically positioned perforator guns (perf guns).**
- **These tests are being conducted in order to provide additional empirical data to enhance IMESAFR in its ability to conduct quantitative risk assessments (QRA) of debris and fragmentation from these guns.**
- **These test results will be used to update the IMESAFR tool, making it able to more accurately predict hazards and risk factors in future quantitative risk assessments (QRAs) relating to these perf guns.**

What are the Primary Test Objectives?

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The primary objectives of these tests in order of priority are:

- **To characterize the following parameters upon forced initiation of the perf gun(s) in each of the emplacement conditions:**
  - **Range, bearing and mass of the debris produced by the perf casing and lubricator (if included)**
  - **Air blast pressures**
  - **Velocity of fragments**

What is the Goal of these Tests?

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- **These perf gun test results will be used to update the IMESAFR tool**

- **This updated analysis will provide a safer working environment through the prevention of injury or death from accidental or unintentional detonation of the perf gun(s) in stored, transitional or deployed situations.**

Equipment Needed for Tests

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- Differential GPS equipment for grid survey and debris recovery
- Multiple normal speed video with fields of view to cover the following areas
  - Still photo photographic equipment
  - High-speed videography equipment
- Blast pressure monitoring equipment that records:
  - Time of arrival
  - Peak pressure
  - Impulse
  - Pressure profile (both positive and negative phase)

Data Collection Activities

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- **Test Analysis Activities**
  - **These tests will include debris documentation including the maximum fragment distance, fragment densities, and the mass distribution of the fragments.,**
  - **The airblast should be recorded with sufficient bandwidth (both high and low frequency) to adequately resolve the peak pressure as well as accurately record both the positive and negative phases of the blast wave.)**
  - **Fragment initial velocities are used to quantify the ballistic limits of debris**

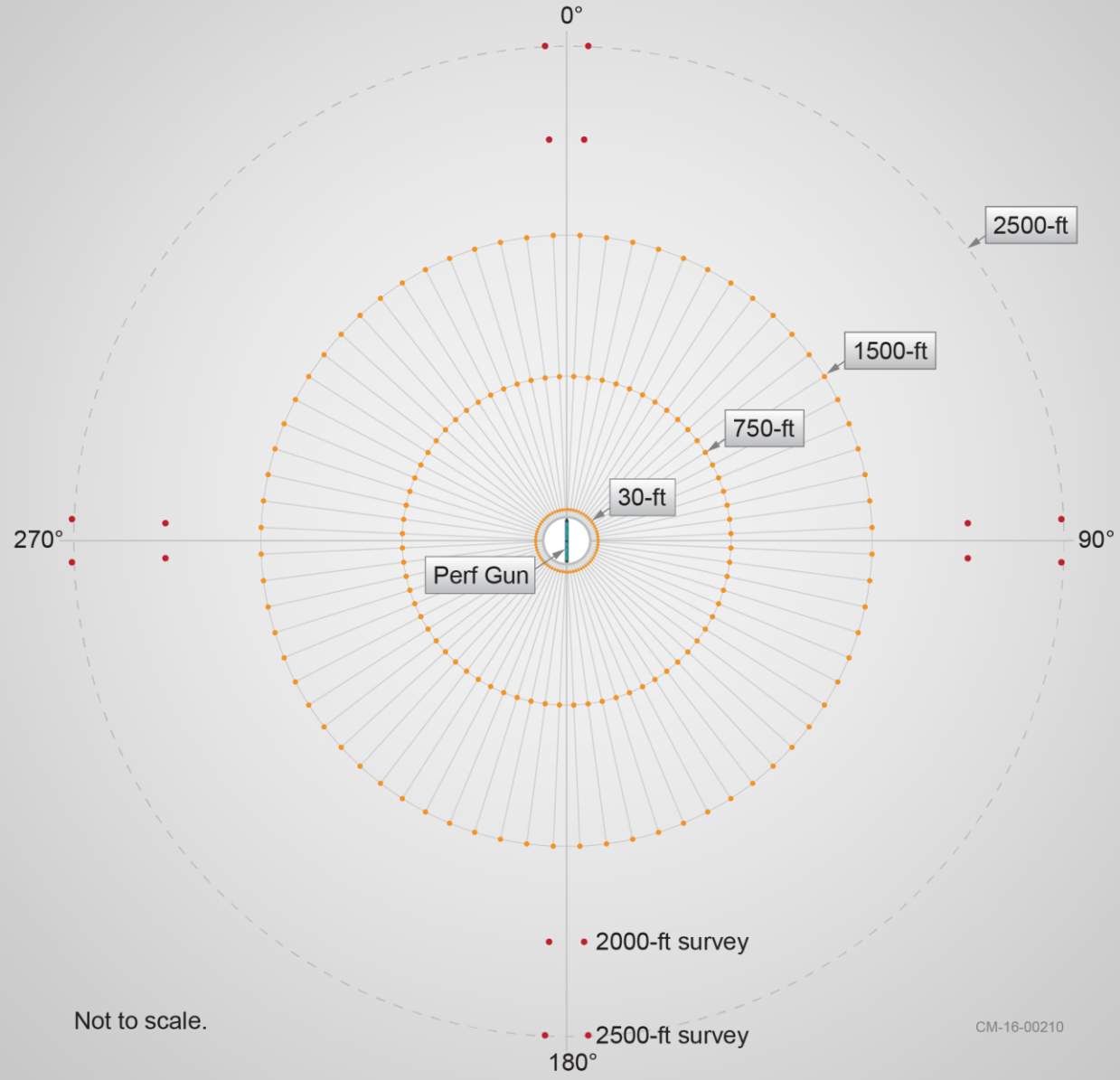

Figure 1: Range Schematic

Test Matrix

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Table 1: Test Parameters

Test	Diameter	Carrier	Length	NEW	Orientation	Purpose
1	7 in	Hollow steel	21 ft	25 lb	Horizontal	Safety Workplace
2	7 in	Hollow steel	21 ft	25 lb	Vertical	Safety Workplace
3	2⅛ in	Capsule gun/spiral gun	20 ft	25 lb	Vertical	Safety/ Workplace
4	2⅛ in	Capsule gun inside fluid filled lubricator	20 ft	25 lb	Vertical	Safety/ Workplace
5	7 in guns	Bundle of eight (8) 7 in guns	10 ft	200 lb	Horizontal	ATF/Storage Regulations

Test 1

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- A 7 inch diameter perforating gun which is 21 feet in length
- A NEW (net explosive weight) of 25 pounds
- Placed on three wooden supports

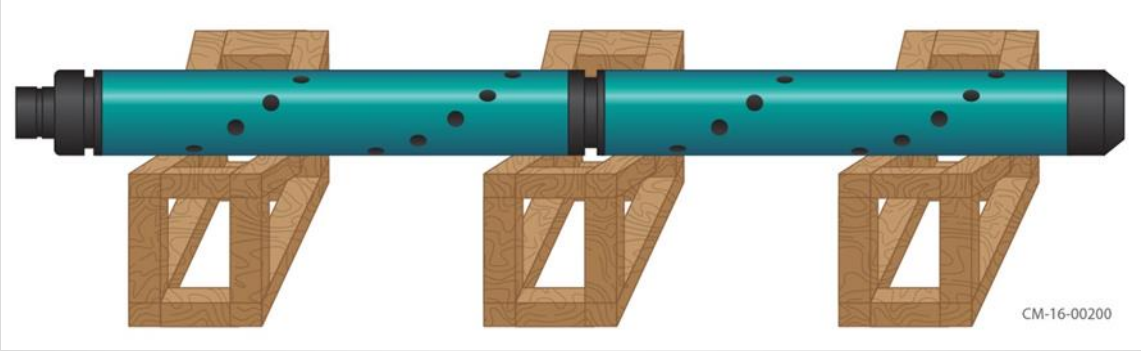

Figure 2: Test 1 Set Up

Test 2, 3 and 4

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- A 7 inch diameter perforating gun which is 21 feet in length
- A NEW (net explosive weight) of 25 pounds
- Placed vertically suspended from a stand or overhang
- Test 3 (capsule gun) and Test 4 (lubricator attached)

Figure 3: Test 2, 3 and 4 Set Up

Test 5

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- A bundle of eight (8) 7 inch diameter perforating gun which is 20 feet in length
- A NEW (net explosive weight) of 25 pounds each or 200 max.
- These stacked perf guns will be simultaneously force initiated.
- The support structure needs to be constructed in a manner as not to impede test monitoring equipment

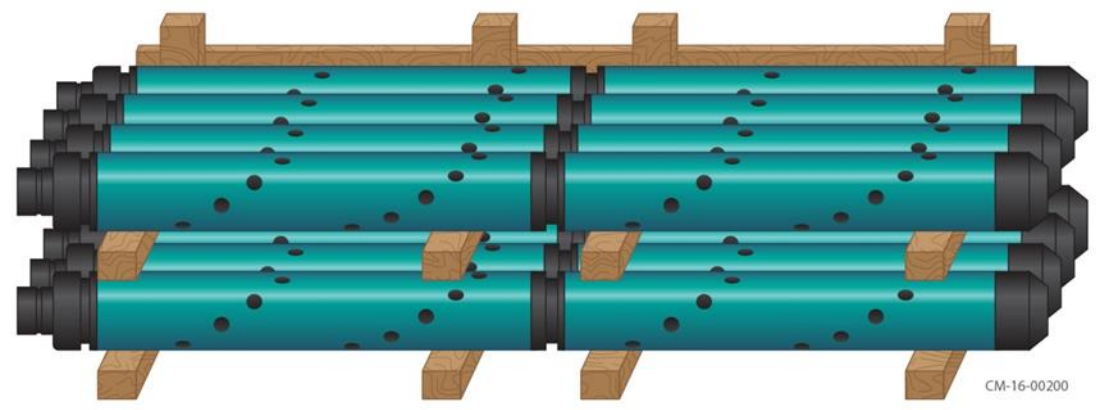

Figure4: Test 5Set Up (8 perf gun stack)

PES (possible explosive site)/ES (exposed site) Orientation

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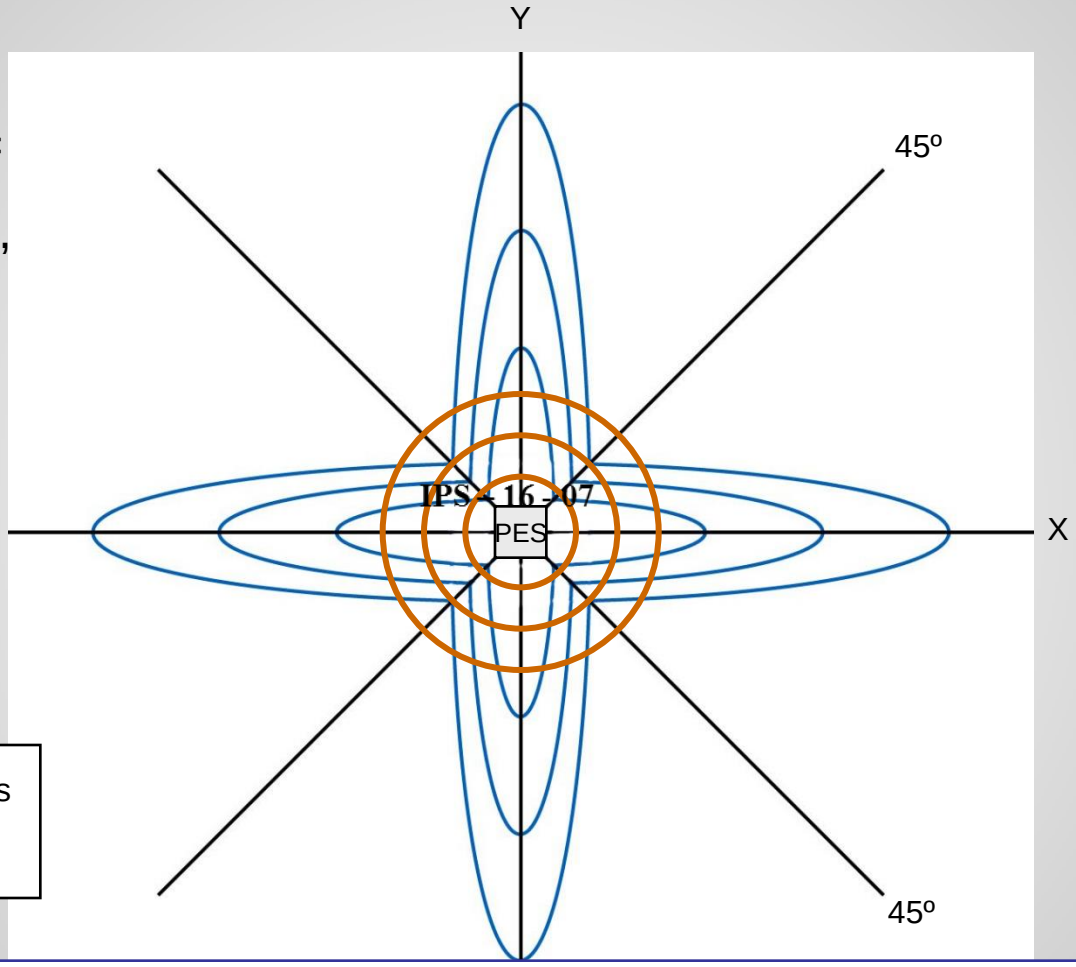
Debris Density =

Σ (roof, front wall, side walls, rear wall)



Note: This debris pattern is not included in IMESAFR Version 1.0.

Prior testing discovered an important debris plot when explosives are in a rectangular or square structure. Perhaps the Perforating gun testing will reveal additional unknown properties

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- Remember:
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    - Free SLPs
    - Videos and posters available
  - My Contact Information
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