



RESEARCH PLAN FOR REQUIRED ECM EARTH COVER

Presented by:
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US Army Corps
of Engineers®

File Name

ERDC
Engineer Research and Development Center

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Magazine EaRth Cover Update/Reassessment study (MERCURY)

Background:

- The **U.S. Army Technical Center for Explosives Safety (USATCES)** has requested support from the U.S. Army Engineering & Support Center, Huntsville (CEHNC) and the U.S. Army Engineer Research and Development Center (ERDC), Vicksburg to develop a plan to address the general issue of the effect of varying earth covers for ECMs.
- Of particular interest is the point at which an ECM behaves as an AGM, both from the perspective of a donor of and an acceptor for explosive loading.
- The DoD Explosive Safety Board (DDESB), Air Force, and Navy (NAVFAC) are also stakeholders with keen interests



U.S. AIR FORCE

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Background (cont):

- The U.S. Army has a large number of earth covered magazines (ECM) for storing ammunition and explosives (AE).
- According to DoD 6055.09-M (*DoD Ammunition and Explosives Safety Standards*), a minimum of 2 ft earth cover shall be maintained over the top of each ECM
- Over time, the earth cover can erode resulting a cover somewhat less than 2 ft thick.
- In accordance with DoD 6055.09-M (*paragraph V2.E5.5.3.2*), “*if earth cover is < 2 ft, the ECM must then be sited as an above ground magazine (AGM)*”.
- This potentially impacts quantity distance (QD) requirements, usually resulting in the need to lower the quantity stored in the magazine.
- The largest impact is on the required intermagazine distance (IMD)

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Background:

- For example:
 - If required to change from ECM to AGM
 - The side-to-side exposure IMD would increase from K1.25 ($D = 1.25 * NEW^{1/3}$) to K6 ($D = 6 * NEW^{1/3}$).
 - For 500,000 lbs NEW, this would increase the IMD from 99 ft to 476 ft.
 - Since the distance between existing magazines cannot be changed, the storage capacity must be drastically reduced.
- The origin of the 2 ft of earth cover requirement is not documented.
- The earliest known ECM designs (Army 652-686 & 652-692 from 1941 and Navy 357428-357430 from 1944) required a minimum of 2 ft of earth cover.
- **However, no basis of design or calculations for these ECM designs have been found.**

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Study Objectives:

- Quantify the relative effects of earth cover thickness on acceptor ECM
- Define the earth cover reduction at which an ECM behaves like an AGM
- Develop relationships between earth cover thickness versus ECM/AGM

Desired Outcome:

- Develop curve(s), supported by data and simulations, that accurately account for the effect of soil cover on blast loading of ECMs, both as a donor and as an acceptor

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Approach:

- Conduct a series of experiments at 1/4-scale* based on the ESKIMO* V full scale test to establish the relative effect of earth cover on the loads imparted to an acceptor ECM. {Experiment NEWs = 922 lbs C4; Equivalent of ~75,500 lbs TNT (full scale)}



ESKIMO: Explosive Safety Knowledge IMprovement Operation

**Peak overpressure will be matched at the 1/4 scale.*

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Approach (cont):

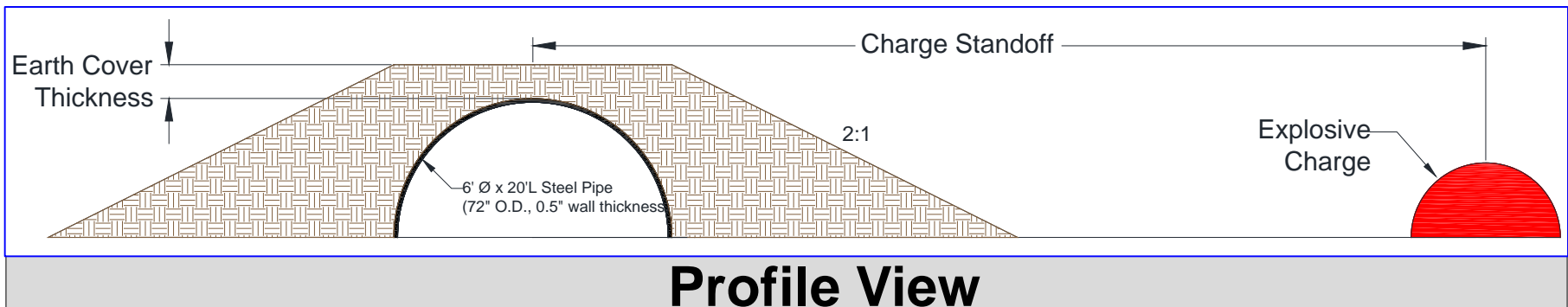
- The acceptor will be a half-buried, rigid steel pipe to simulate an ECM structure shape.
- A well-characterized soil backfill will be emplaced to provide a consistent, known soil material on, around and beneath the acceptor ECM.
- The same soil conditions will be used to construct the soil berm over the ECM.
- Airblast will be measured over a scaled distance (K) of 2.0 to 11.0, with primary emphasis at the acceptor location.
- The soil loads transmitted directly to the acceptor's surface will also be measured on the simulated acceptor's surface.

**Peak overpressure will be matched at the 1/4 scale.*

Magazine EaRth Cover Update/Reassessment studY (MERCURY) – Series 1 Experiment Matrix (1/4th Scale)

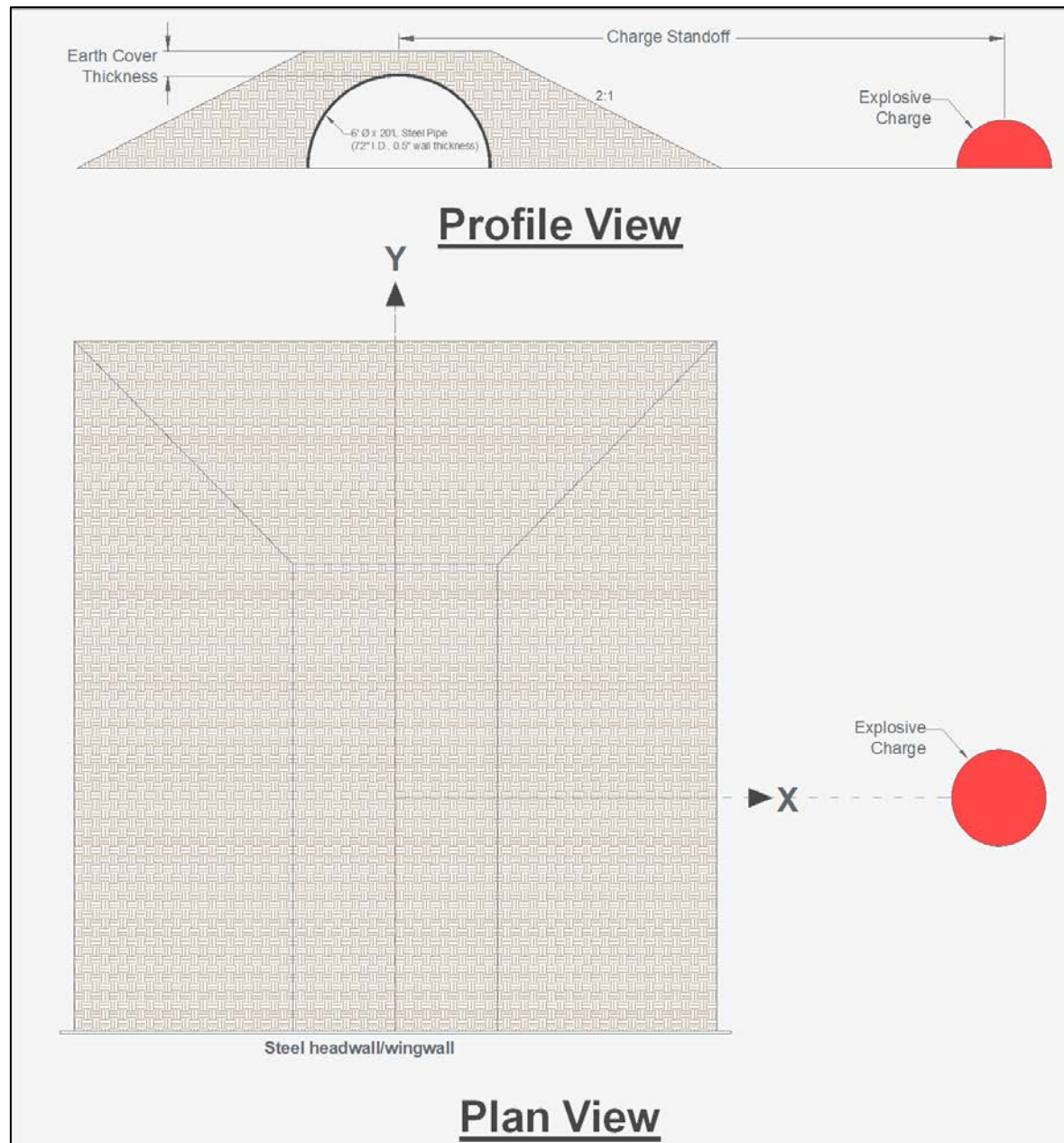
Experiment	Acceptor ECM	Donor Charge Type	Donor C4 Eq. Charge Weight, lb	Charge Scaled Standoff*	Charge Standoff, ft	Full-scale earth cover, ft	1/4th scale earth cover, ft
M1	Rigid Simulated Arch (6ft Ø Steel Pipe)	Bare C4	922	2.0	21.13	3	0.75
M2	Rigid Simulated Arch (6ft Ø Steel Pipe)	Bare C4	922	2.0	21.13	2	0.50
M3	Rigid Simulated Arch (6ft Ø Steel Pipe)	Bare C4	922	2.0	21.13	1	0.25

*K distance is approximately 1.25

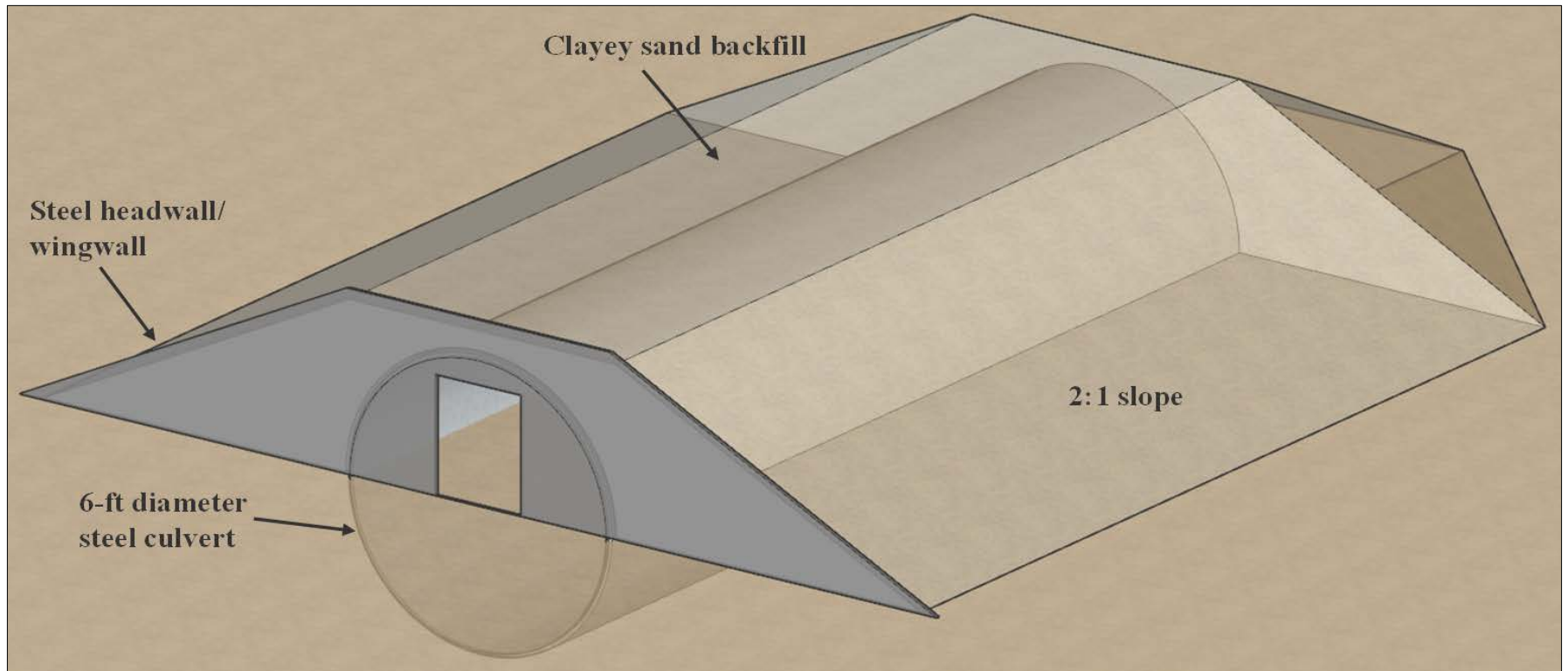


ECM Configuration

- Simulated arch magazine
- 2:1 side slopes
- Charge placed off side of ECM

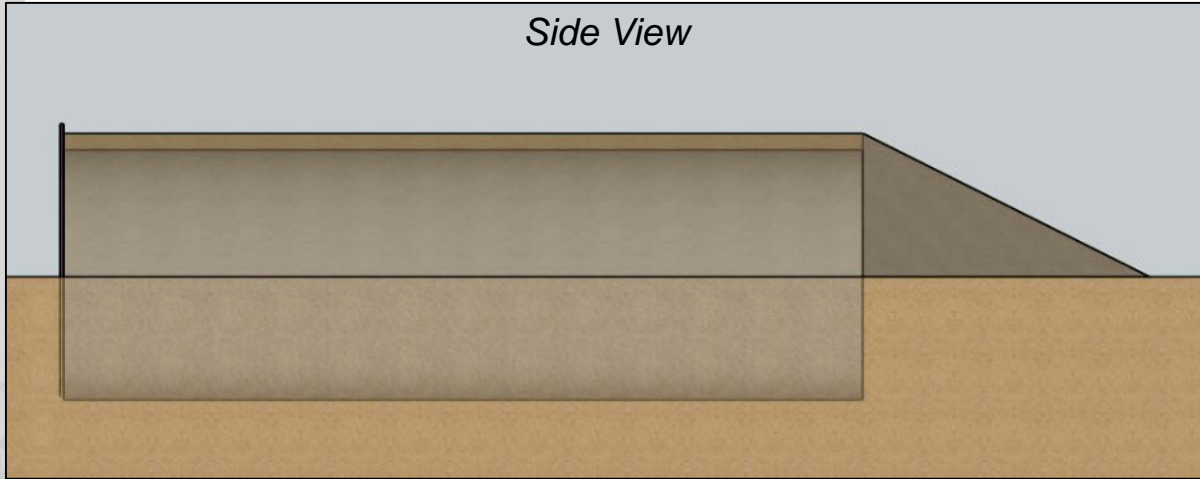


ECM Configuration

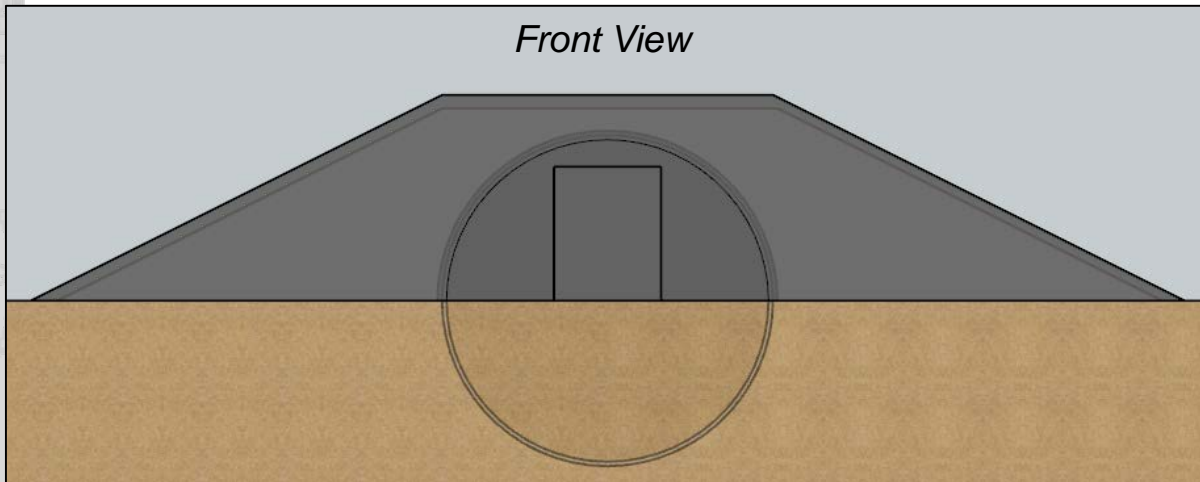


Example of ECM Configuration

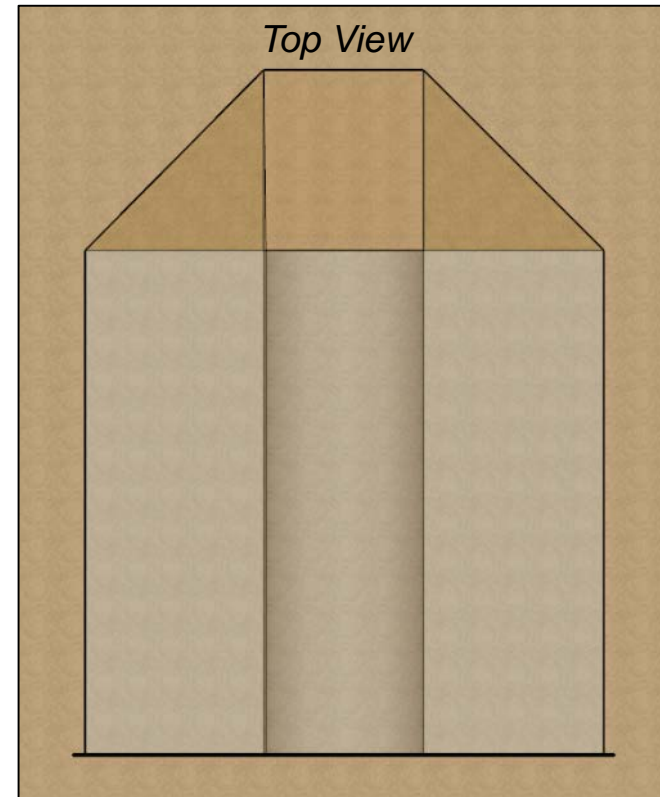
Side View



Front View

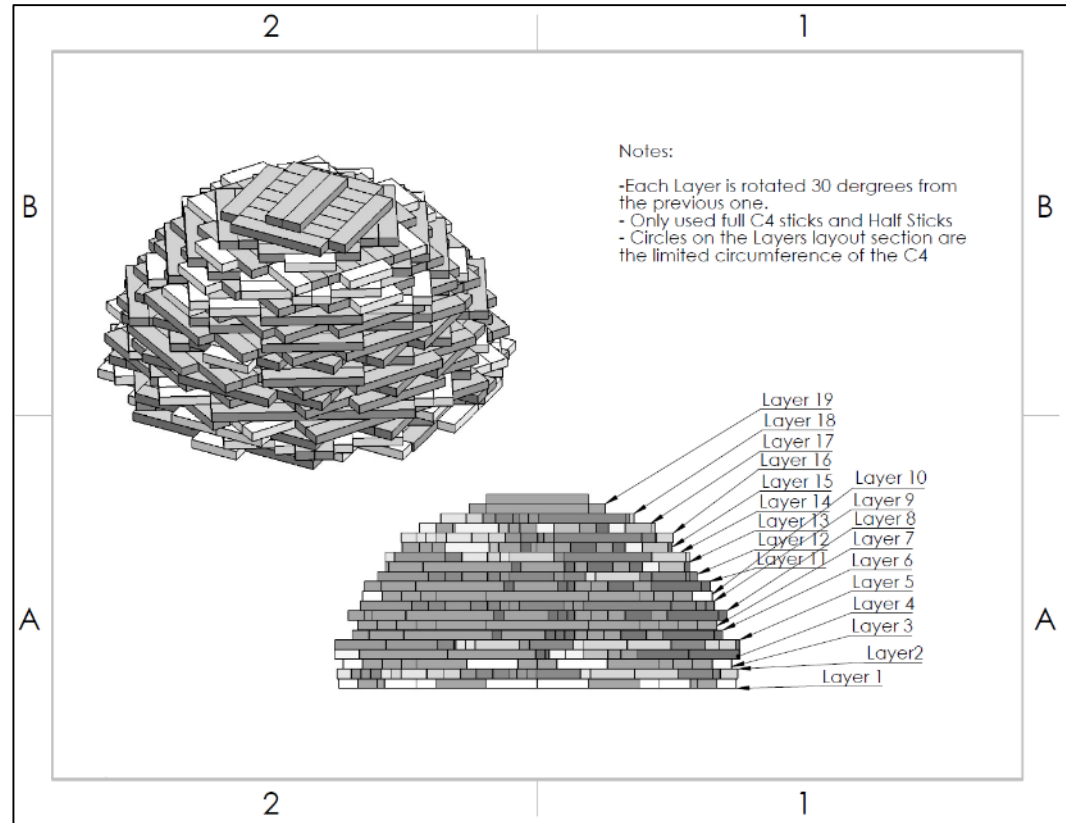
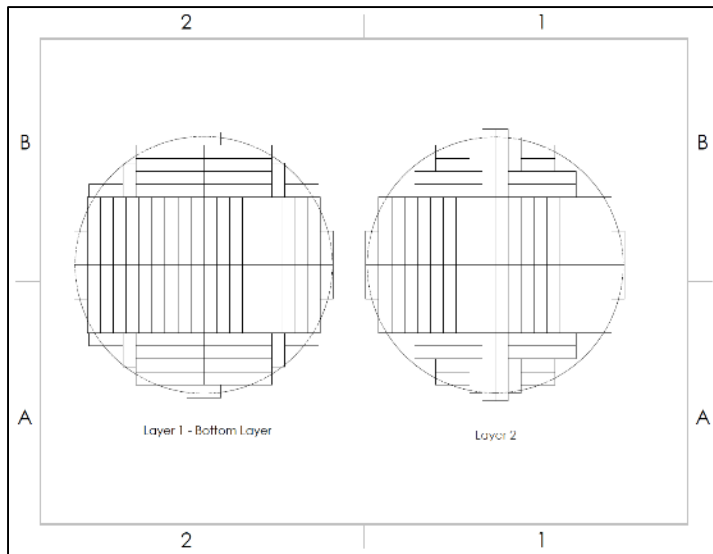


Top View

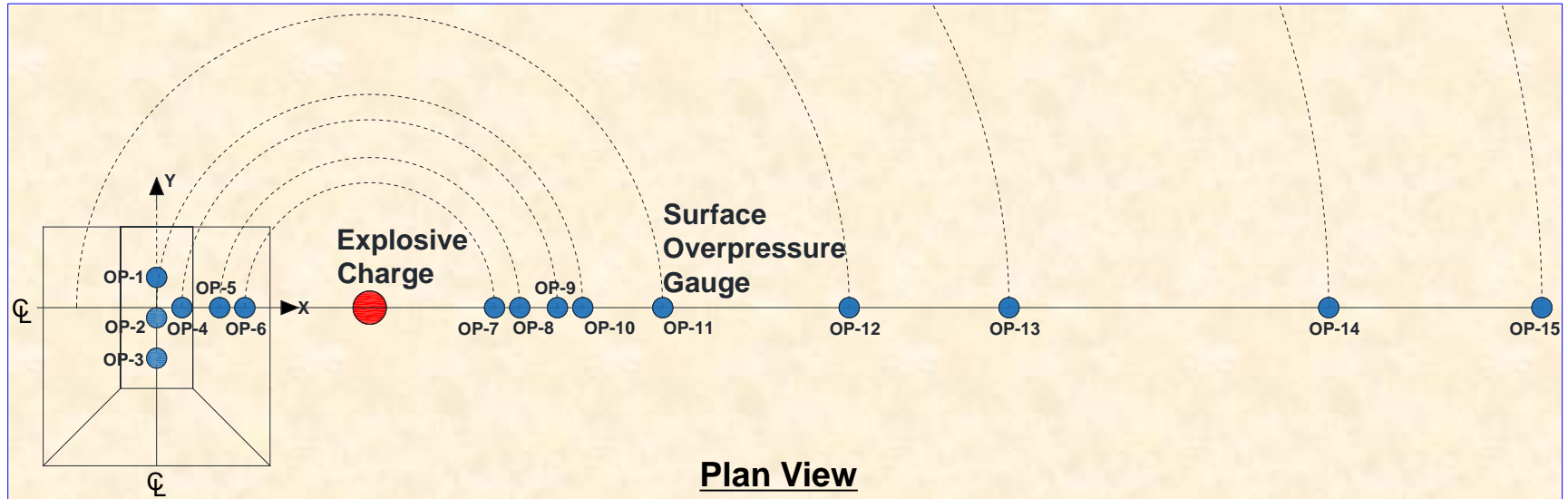


Donor Charge Configuration

- 922-1b C4
- Hemispherical configuration



Overpressure Gauge Locations Mercury 1,2,3

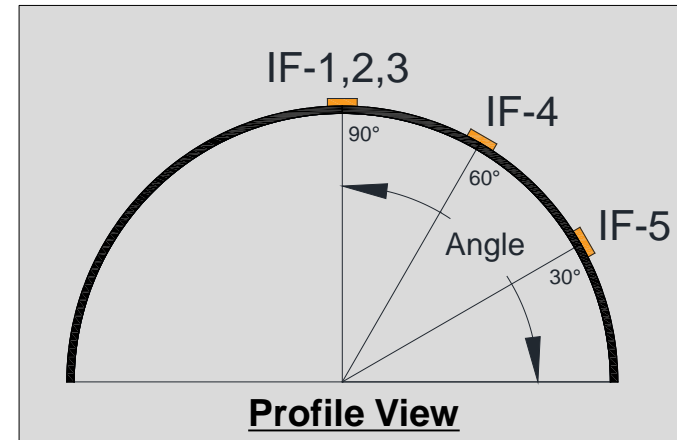
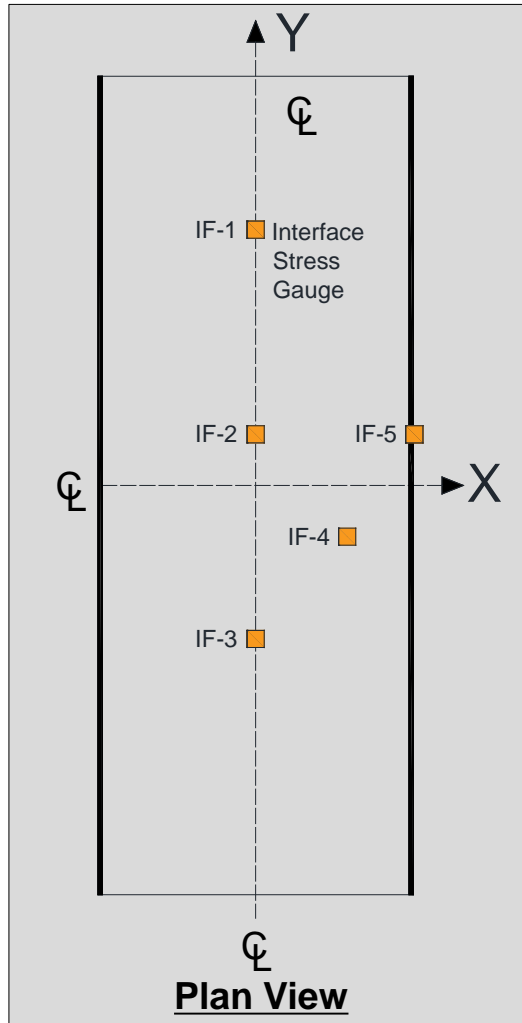


Gauge Number	X Distance (ft)	Y Distance (ft)	Distance from Charge, ft	Scaled Distance (ft/lb ^{1/3})	Gauge Number	X Distance (ft)	Y Distance (ft)	Distance from Charge, ft	Scaled Distance (ft/lb ^{1/3})
OP-1	0.00	3.00	21.34	2.02	OP-9	39.75	0.00	18.62	1.76
OP-2	0.00	-1.00	21.15	2.00	OP-10	42.26	0.00	21.13	2.00
OP-3	0.00	-5.00	21.71	2.05	OP-11	50.19	0.00	29.06	2.75
OP-4	2.51	0.00	18.62	1.76	OP-12	68.68	0.00	47.55	4.50
OP-5	6.25	0.00	14.88	1.41	OP-13	84.53	0.00	63.40	6.00
OP-6	8.75	0.00	12.38	1.17	OP-14	116.23	0.00	95.10	9.00
OP-7	33.51	0.00	12.38	1.17	OP-15	137.37	0.00	116.24	11.00
OP-8	36.01	0.00	14.88	1.41					

Note: All scaled distances are based on TNT equivalence.

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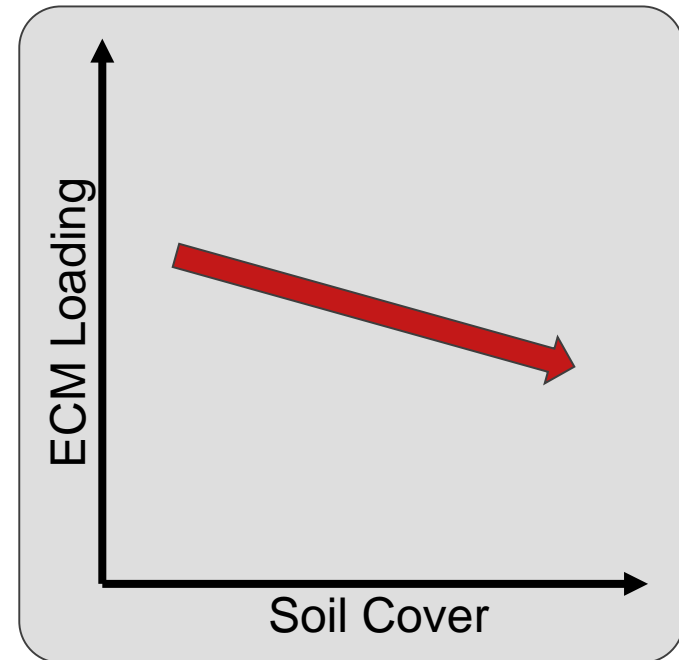
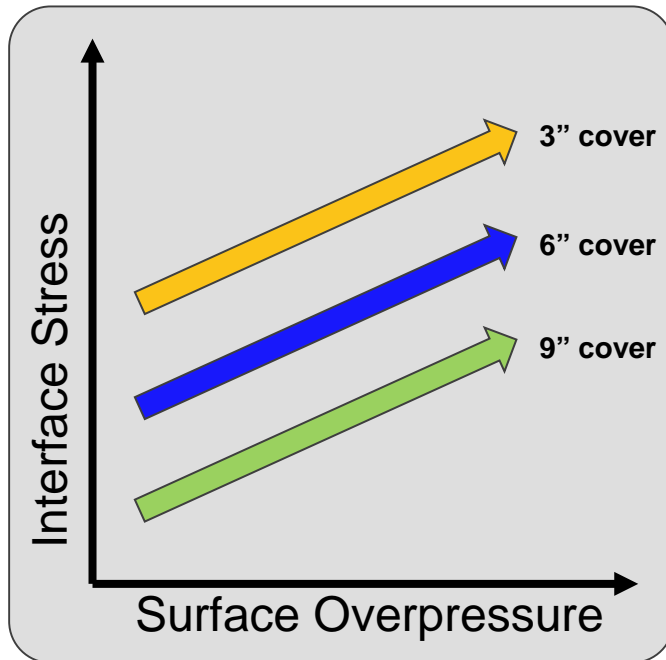
Interface Stress Gauge Locations Mercury 1,2,3



Gauge Number	X Distance (ft)	Y Distance (ft)	Angle (deg)
IF-1	0.00	5.00	90
IF-2	0.00	1.00	90
IF-3	0.00	-3.00	90
IF-4	1.79	-1.00	60
IF-5	3.10	1.00	30

Expected Results

- Develop an understanding of the relationships of soil cover vs acceptor ECM loading
- Establish reliable baseline for ECM loading @ 2 ft earth cover
- Identify relative % reduction in ECM loading for cover less than 2-ft



Magazine EaRth Cover Update/Reassessment study (MERCURY) – Series 1 Test Schedule

Location: ERDC Test Facility – Fort Polk, LA

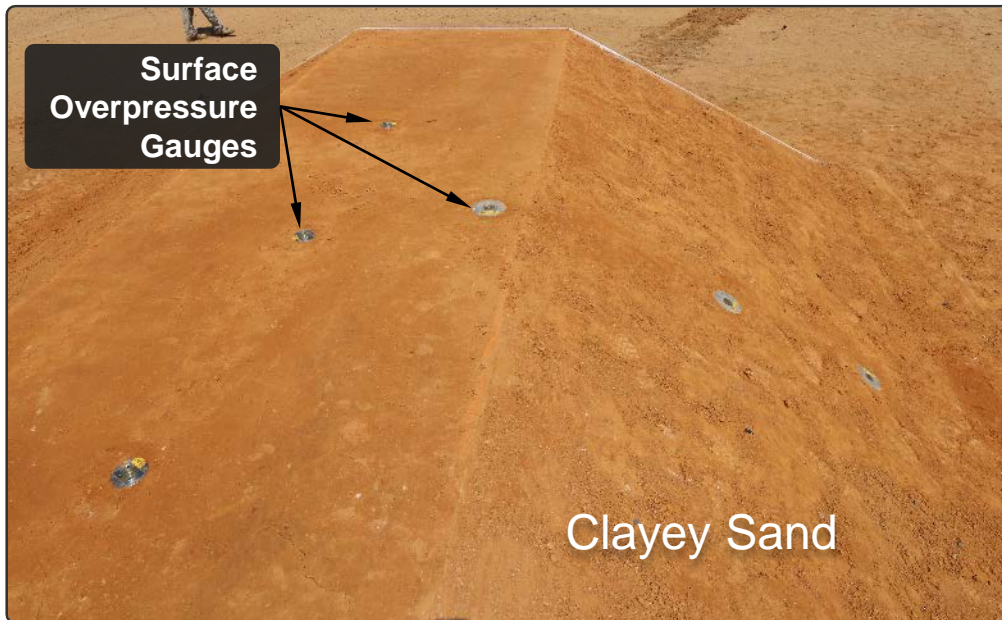
- **Field preparation: 16 – 20 July 2018**

- **Test Execution: 23 July – 3 Aug 2018**
 - 24 July – MERCURY 1
 - 26 July – MERCURY 2
 - 1 Aug – MERCURY 3

MERCURY Experiment #1 – Completed 24-JUL 2018



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Path Forward / Future Work

- The ultimate purpose of this experimental effort is to provide sufficient data and clear justification for updates to the current ECM cover requirements stated in the *DoD Ammunition and Explosives Safety Standards*.
- Analysis and data reduction of the test results is currently underway
- Future testing is planned in FY19 under Series #2
- The results of MERCURY Series 1 will guide experiments proposed for FY19 to further understand the effect of earth cover on acceptor ECM loading due to airblast and fragmentation.
- In addition, the results will provide benchmark data for comparison to and verification of proposed companion numerical simulations
- Numerical simulation will be used as a means of augmenting and expanding the parametric evaluation of the effect of ECM earth cover.

Questions?