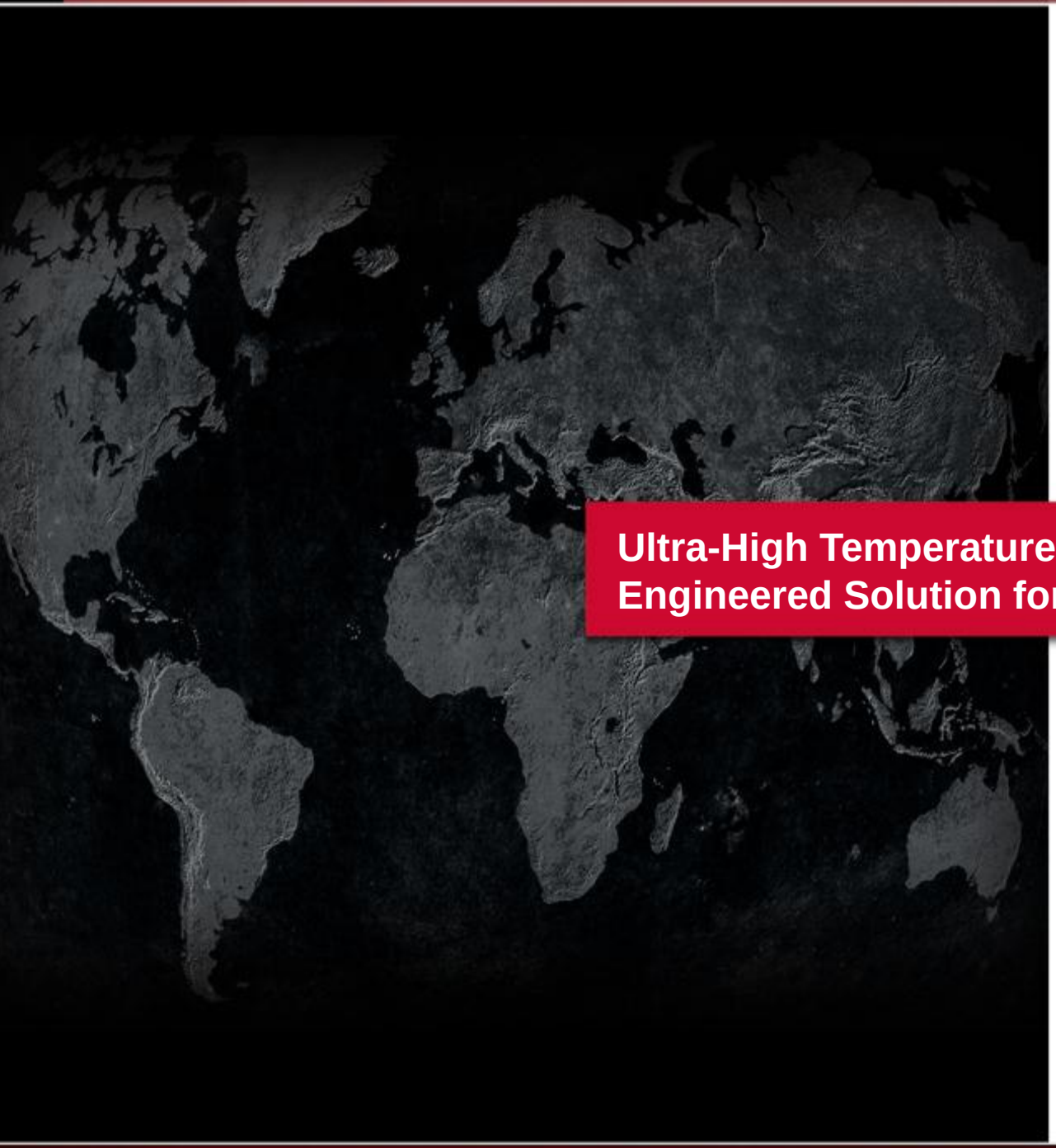

Ultra-High Temperature Explosive System: An Engineered Solution for an Operator in Malaysia

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Technology Manager

APPS-13-007

HALLIBURTON

Background

- Perforating solutions needed for 250C (480F), 100 hours
  - Convey with TCP
  - Four gun sizes: 2.00, 2.88, 3.38, 4.63 inches

- Contingency plans included:
  - Coil tubing and wireline conveyance
  - Slickline retrievable firing head

- Two-part program undertaken:
  1. Push the established time-temp limit of HNS
  2. Develop explosive systems beyond HNS

Explosive components in system

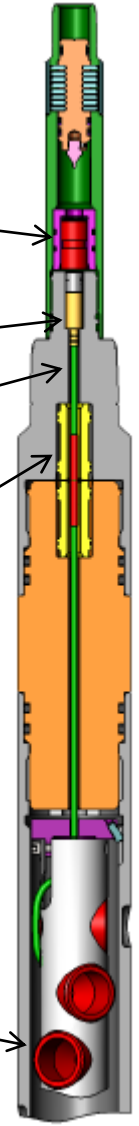
Percussion detonator

Detonating cord initiator

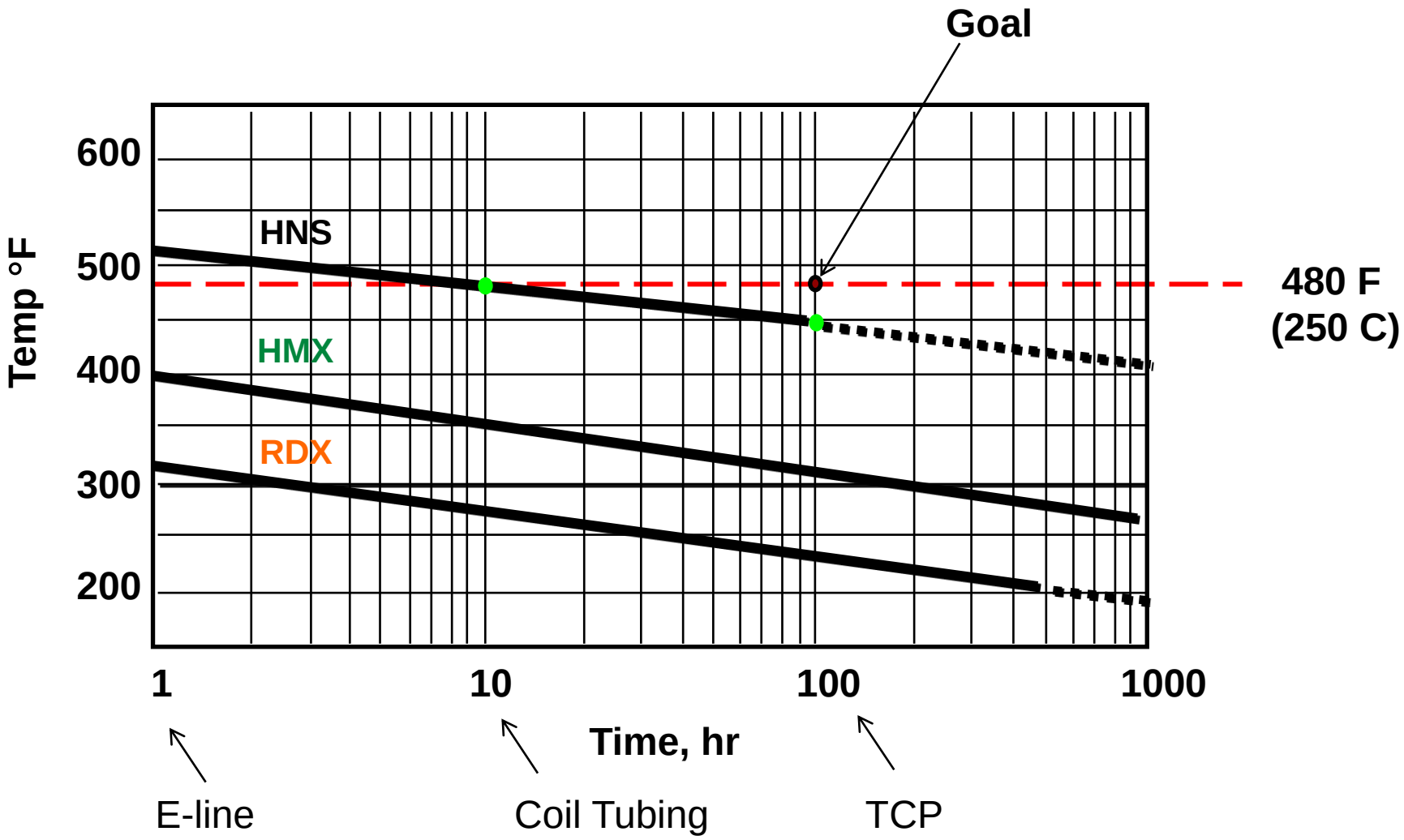
Detonating cord

Bi-directional booster

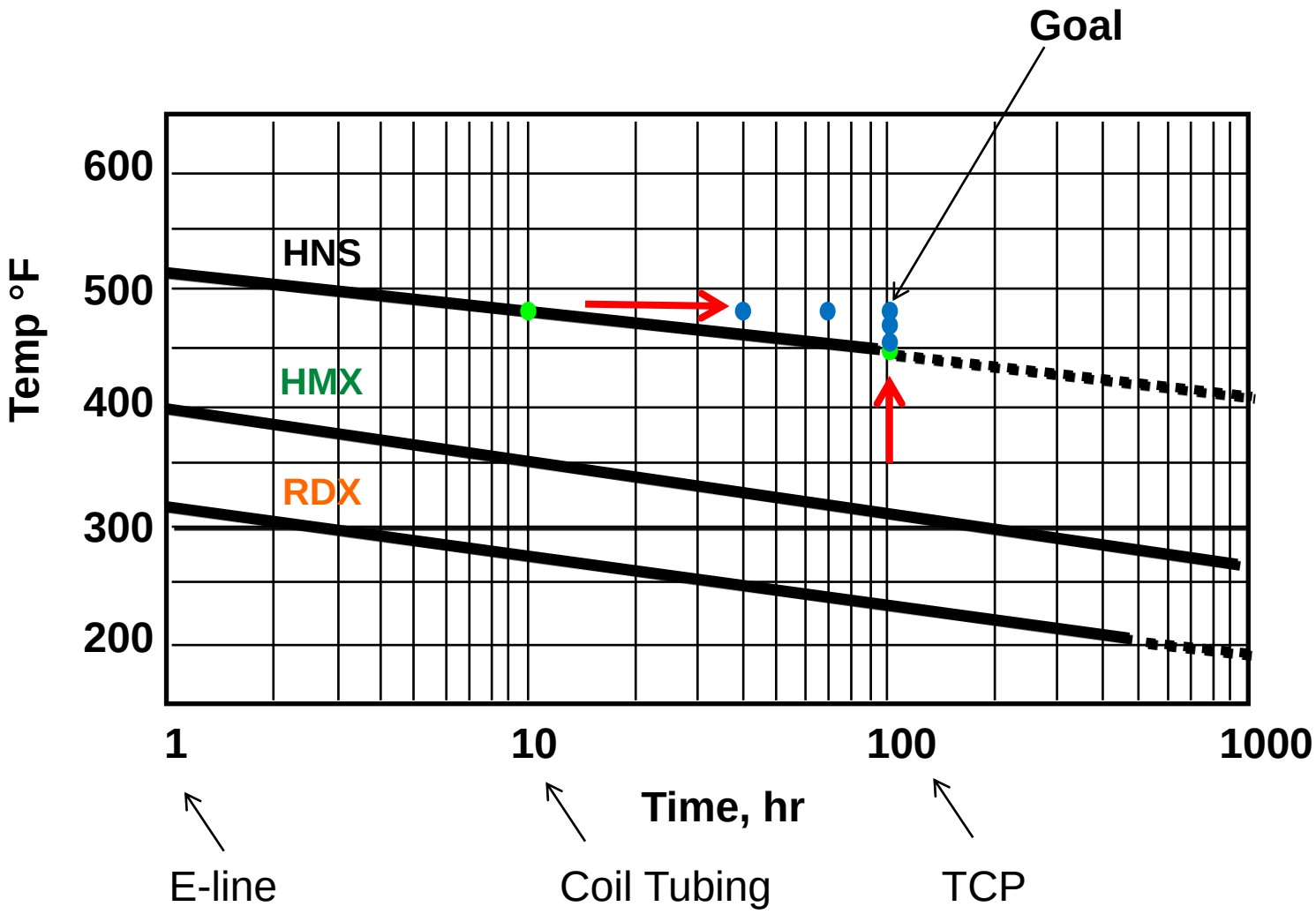
Shaped charge



Time-temperature chart for explosives



Push HNS limit – test in both directions…

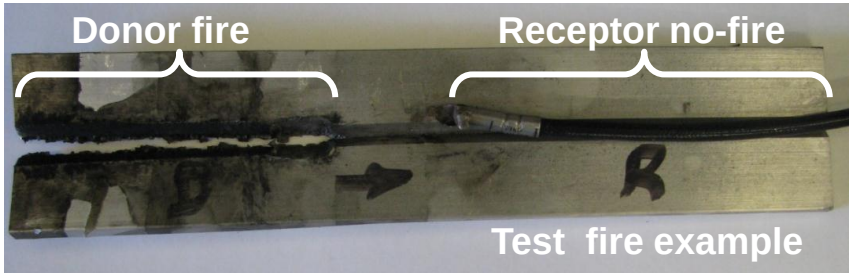


Initial HNS tests

Thermal test facility

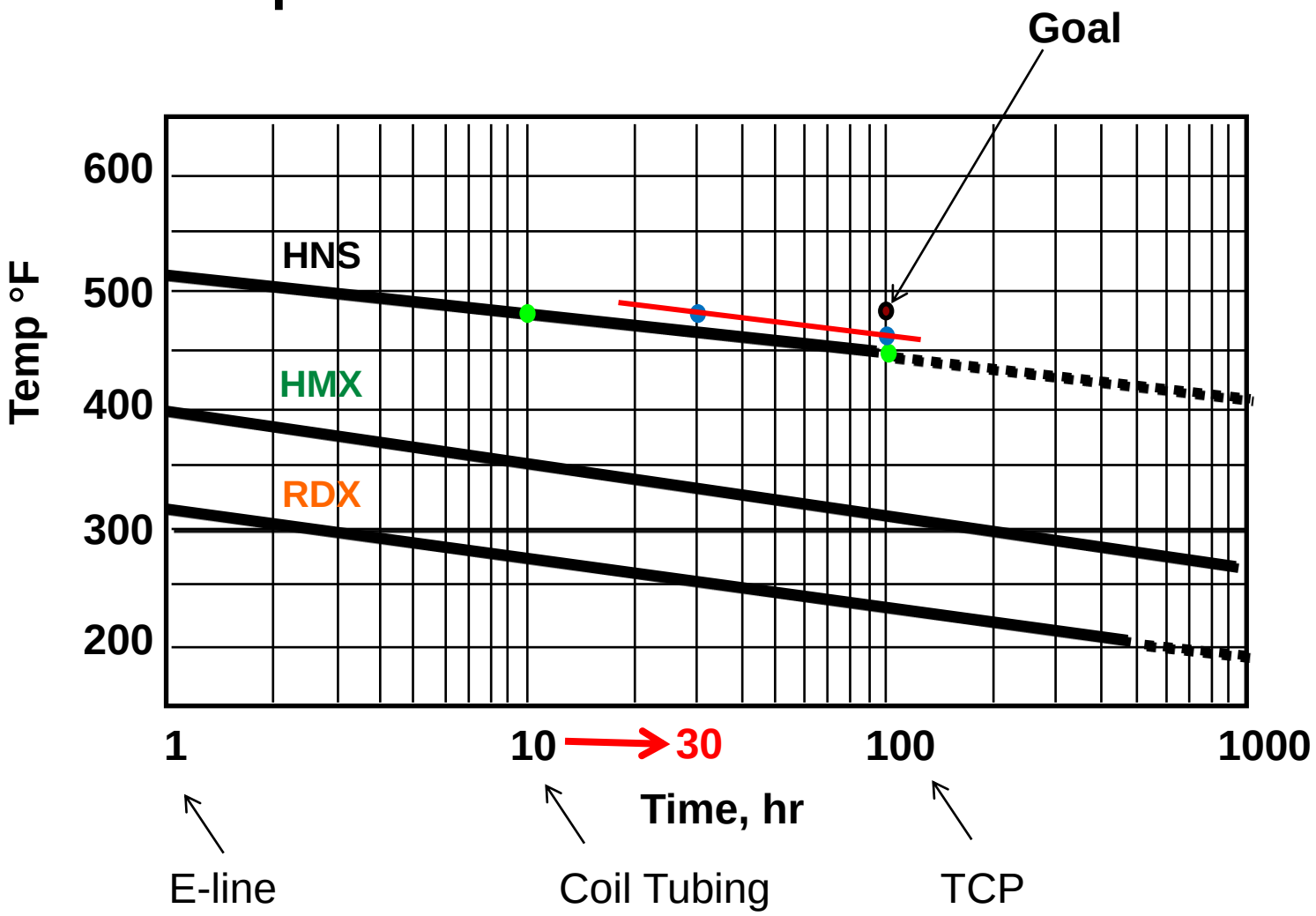

Oven

- Small scale for safety
- Used detonating cord and bi-directional boosters
- Failure to transfer signified thermal limit



	Oven A		Status	Wt loss %	Oven B		Status	Wt loss %
Test No.	Time, hrs	Temp, F			Time, hrs	Temp, F		
1	100	450 (232C)	Complete, successful	1.6	10	480 (250C)	Complete, successful	1.7
2	100	460 (238C)	Complete, successful	1.7	30	480 (250C)	Complete, successful	0.6
3	100	470 (243C)	Failed transfer	3.5	40	480 (250C)	Failed transfer	3.2
4	100	480 (250C)			70	480 (250C)		
5					100	480 (250C)		

The initial tests showed an adjusted time-temp line for HNS was possible…



Scale-up test with shaped charges

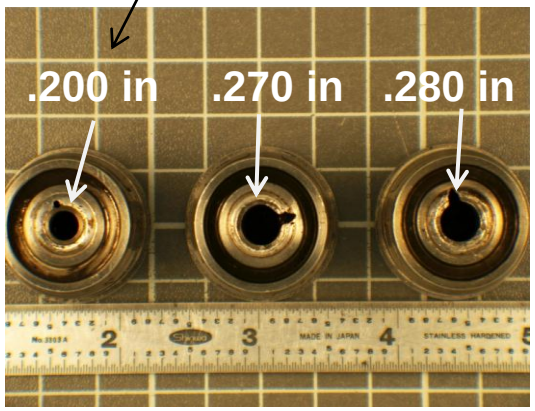
- Free air/explosive ratio is important due to decomposition gases
- Charges can become desensitized
- Conditions: 480F, 30 hrs

Gun Size (in)	Typical gun length (ft)	Max gun length thermally allowed (ft)
2.00	21	15
2.88	22	22
3.38	22	16
4.63	22	22

Initiator tests

- Conducted oven tests with two devices, A & B
- Measured output diameters
- Device B chosen, still robust beyond +30 hrs exposure

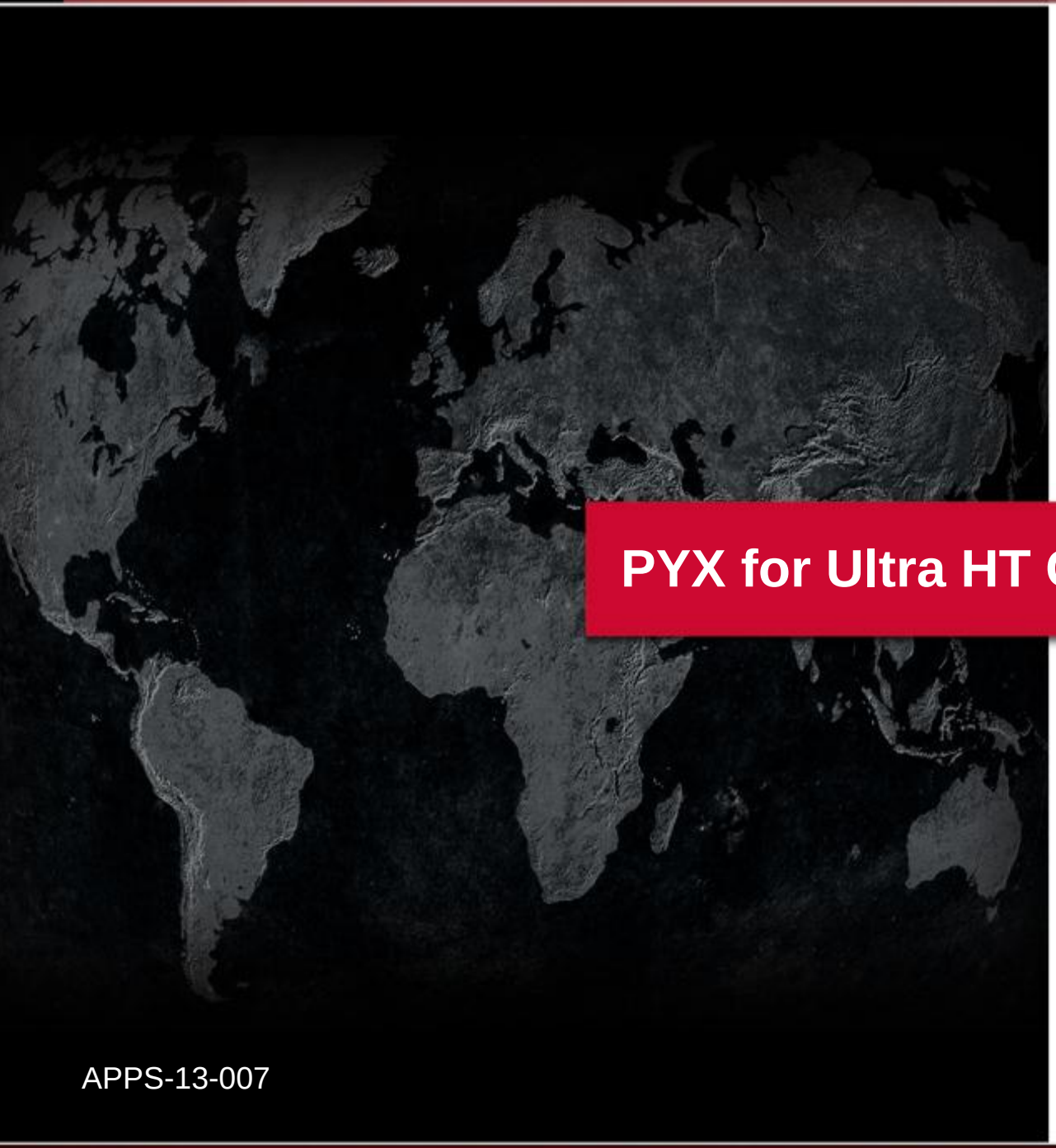
27% reduction using explosive A at 30 hrs



	480 F @ 30 hrs	480 F @ 50 hrs
Sample No.	Device A, using explosive A (Output dia, in)	Device B, using explosive B (Output dia, in)
1	.200	.299
2	.270	.306
3	.280	.295

HNS system integration tests: 480F for 30 hrs

Gun Size (in)	Outcome	Benchmark Steel Pen (in)	Post-test Steel Pen (in)
2.00	All fire	2.86	2.30
2.88	All fire	4.85	4.06
3.38	All fire	6.02	4.59
4.63	All fire	7.76	5.72



PYX for Ultra HT Capability

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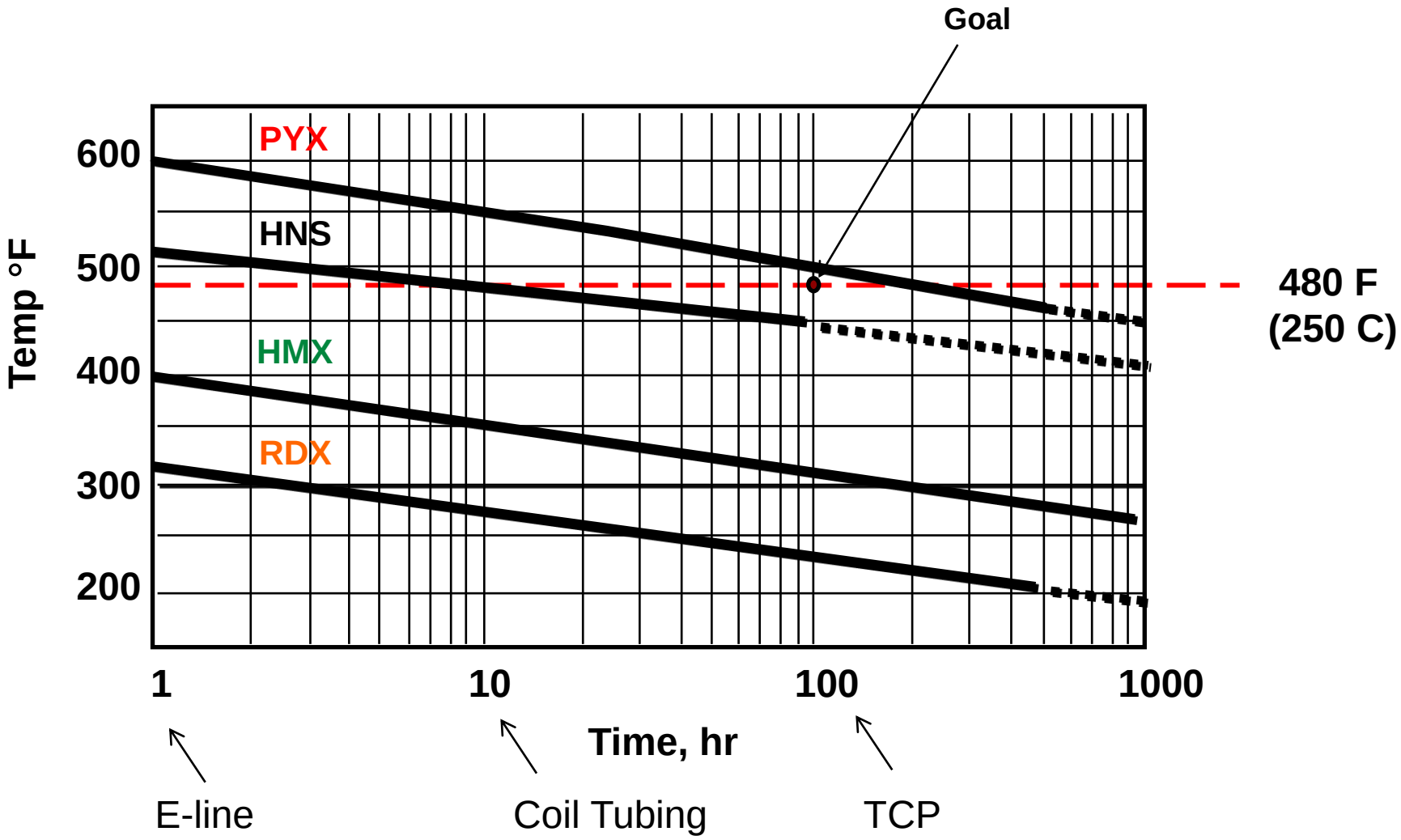
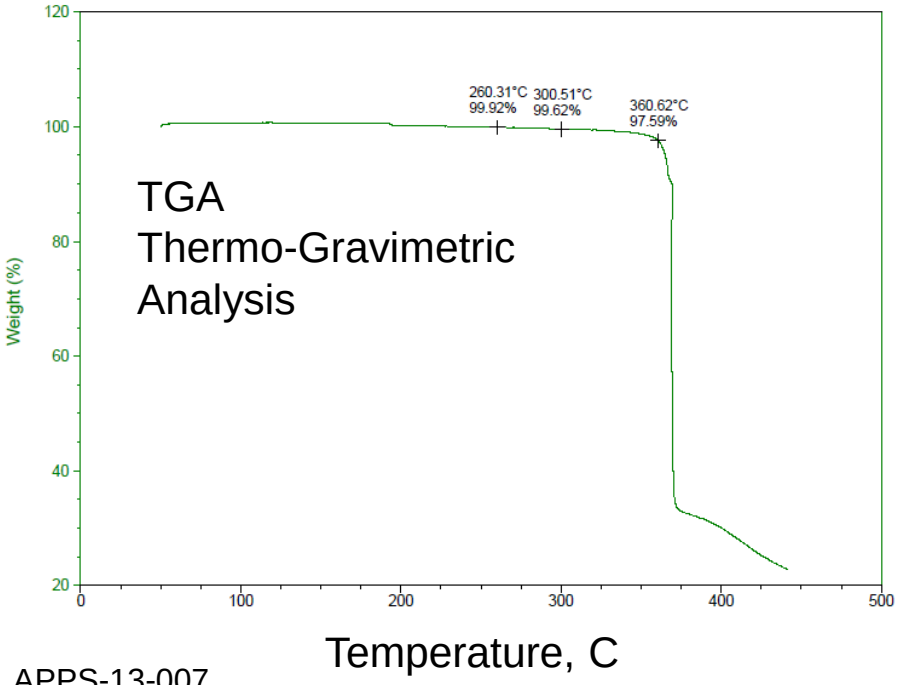
Time-temperature chart for explosives



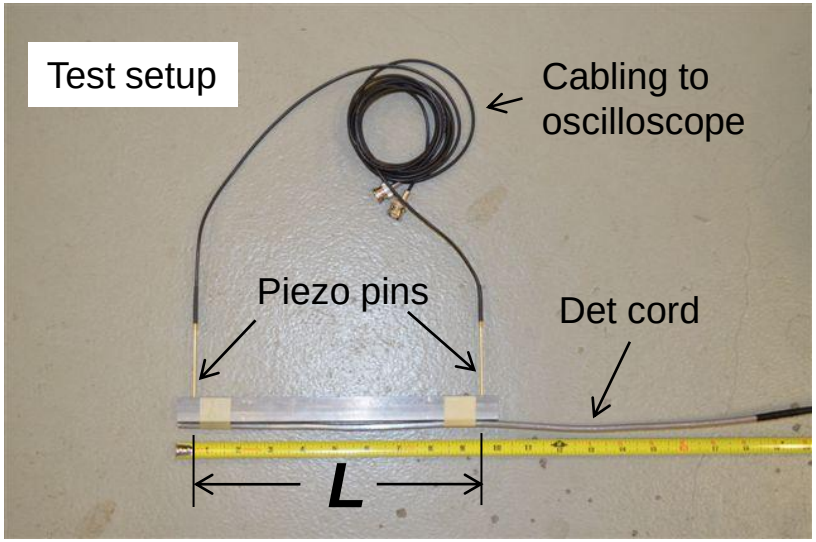
New PYX supply chain established

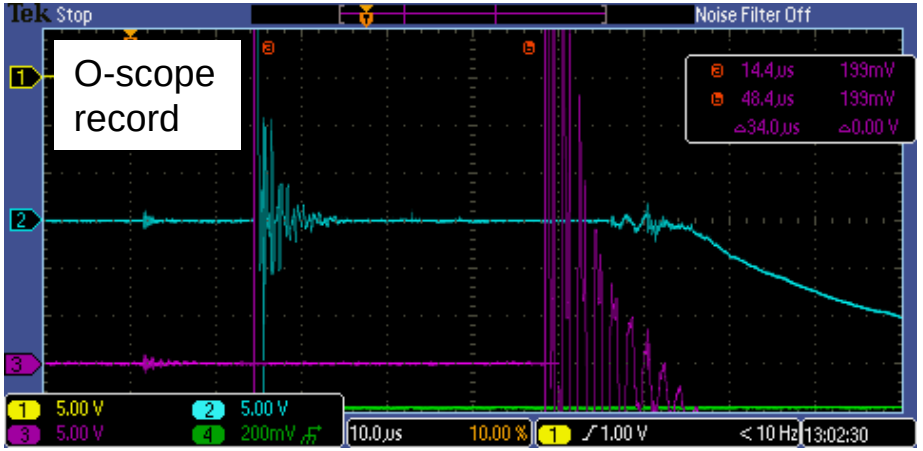
- **High purity production underway**
- **Detonating cord production underway**



PYX crystalline structure (tailored for oilfield products)

PYX det cord – velocity of detonation tests





Benchmark (m/s)	Conditioned to 480 F for 100 hrs (m/s)	PYX powder era
6723	6684	1990s
7034	6824	2012

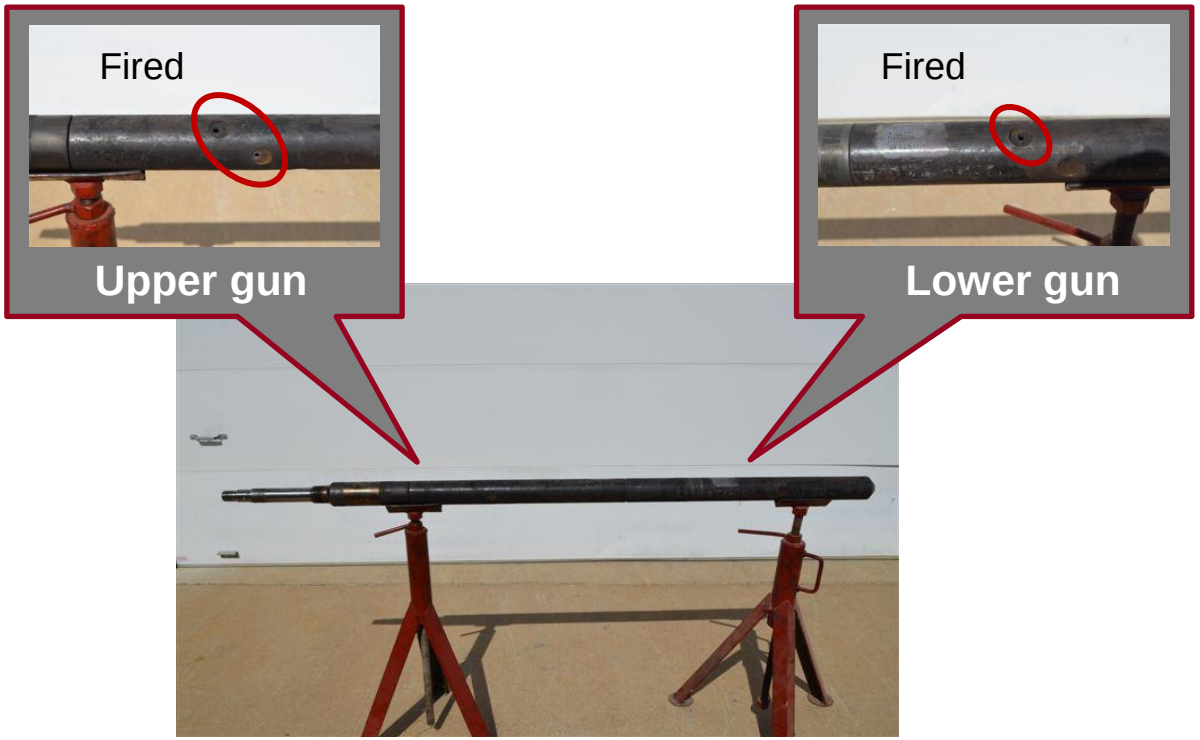
PYX shaped charge performance in QC concrete targets

Gun size (in)	Charge	Penetration Performance (day of mfg)	Penetration Performance (28d storage)	Charge interference test at 6 SPF
2.88	125 PYX	15.0 in	15.8 in	Passed
3.38	220 PYX	20.0 in	22.1 in	Passed

Aging tests passed

PYX system integration tests

- Gun systems tested to:
  - 480F, 100 hrs
- Initiating system tested to:
  - 480F, 50 hrs
  - 470F, 100 hrs



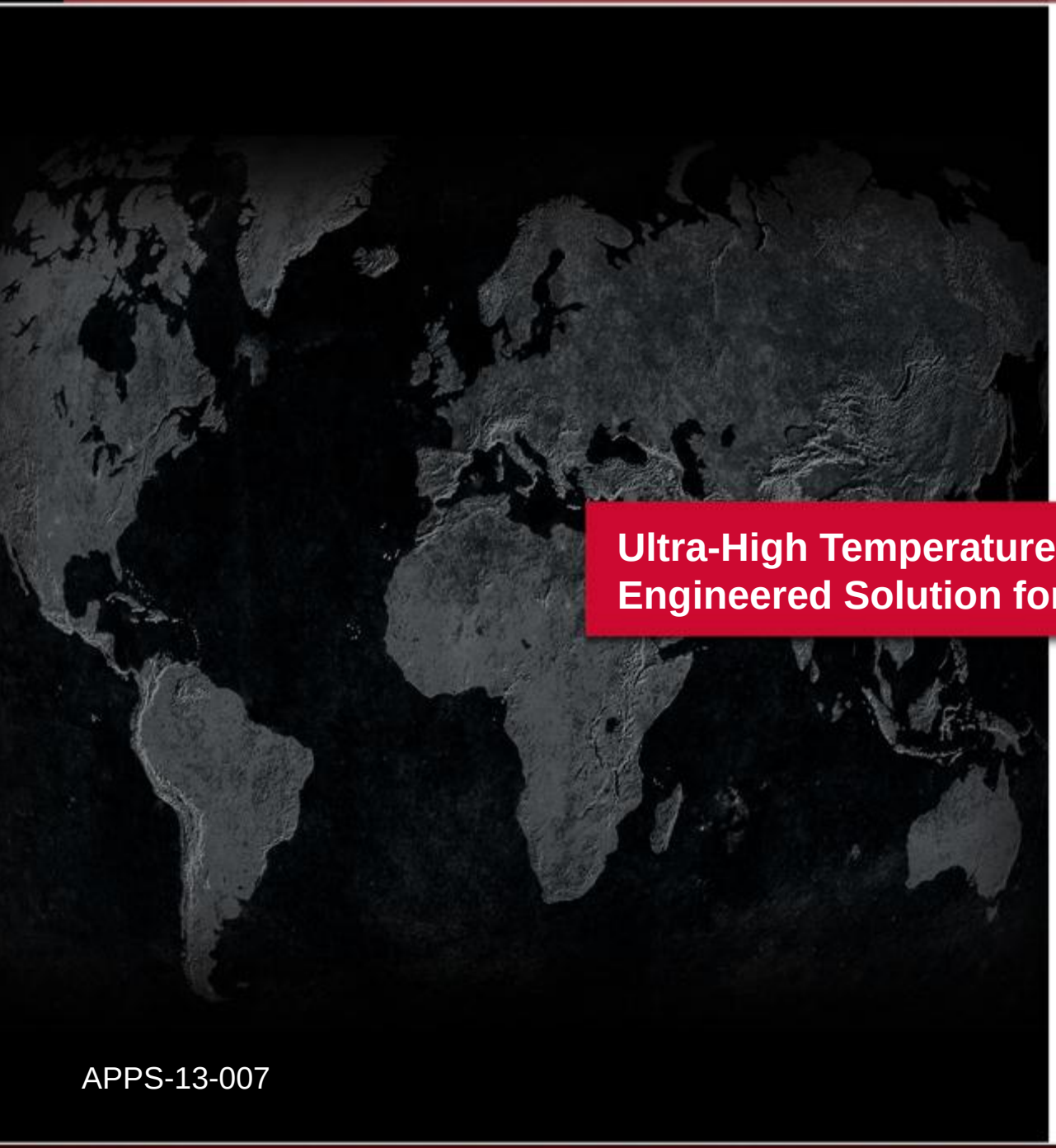
Gun Size (in)	Outcome	Benchmark Steel Pen (in)	Post-test Steel Pen (in)
2.88	All fire	4.86	3.77
3.38	All fire	6.38	5.10

Future work – Section IV testing with temperature

- Allows charge performance in stressed rock to be evaluated after exposure to time and temperature

Summary

- HNS explosive systems were qualified to higher levels for time and temperature
  - Tested at both component and system levels
  - Free air/explosive ratio is important
  - Job could be conducted with max 30 hour conveyance
- PYX systems have been qualified with successful results
  - Higher time/temp rating than HNS
  - PYX supply chain in place
- Heated Section IV tests will be used to evaluate charge performance after exposure to time & temperature



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Thank You

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