Processing of Rocket Motors at the Anniston Static Detonation Chamber (SDC)

June 2015

Presented to:

CWD

Presented by:

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M28 Rocket Motor Propellant

Armament Research Development and Engineering Center received M67 rocket motor assemblies from Blue Grass Chemical Activity to be tested for safety in storage

- (23) M28 propellant grains were removed from the rocket motor assemblies, cut and analyzed

These were sent to Anniston for processing in the Static Detonation Chamber (SDC)

- To determine processing parameters
- To obtain emissions data
- To gain initial information as to whether the SDC is a possible option for M67 rocket motor processing

M28 Rocket Motor Propellant

- M28 Rocket Motor Grains
  - 19.35 pounds with Inhibitor Layer
  - 18.07 NEW without Inhibitor Layer
  - Class 1.3 Explosive

M28 Rocket Motor Propellant

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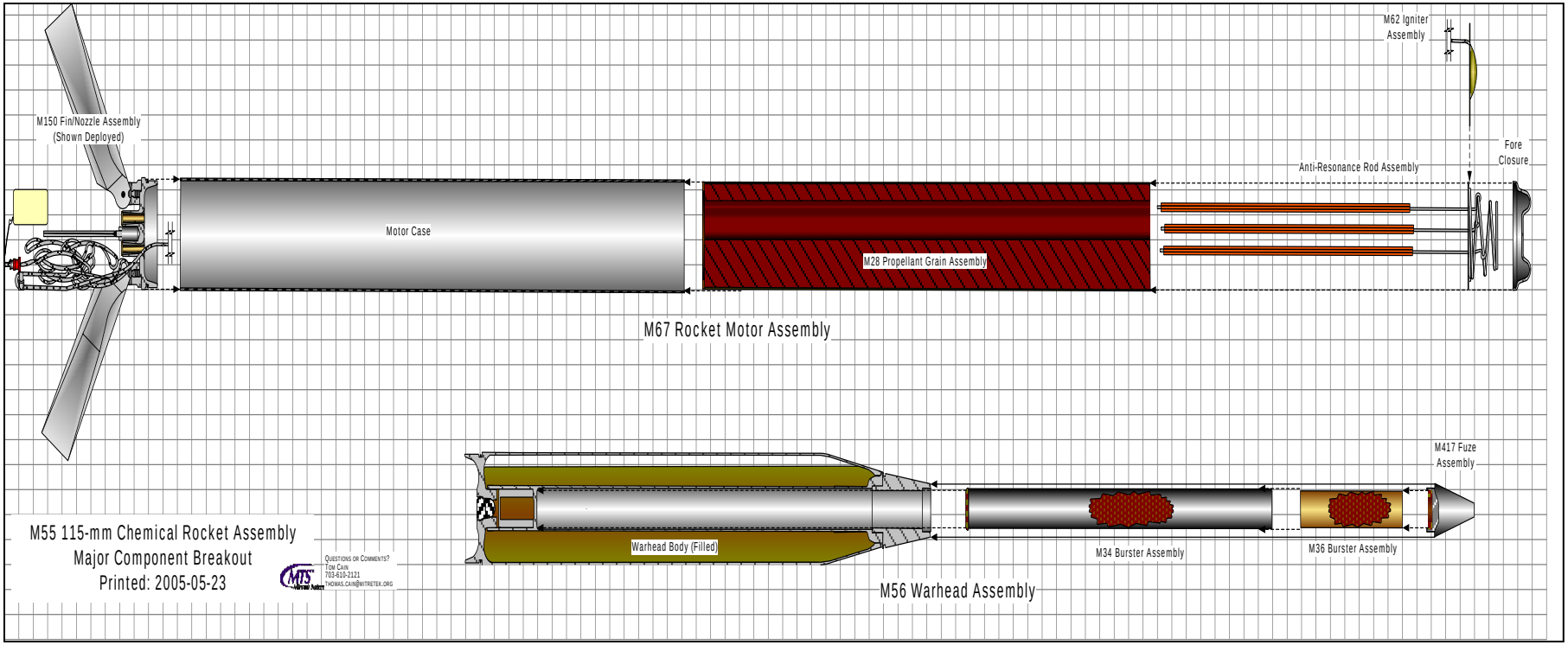

M28 Rocket Motor Propellant

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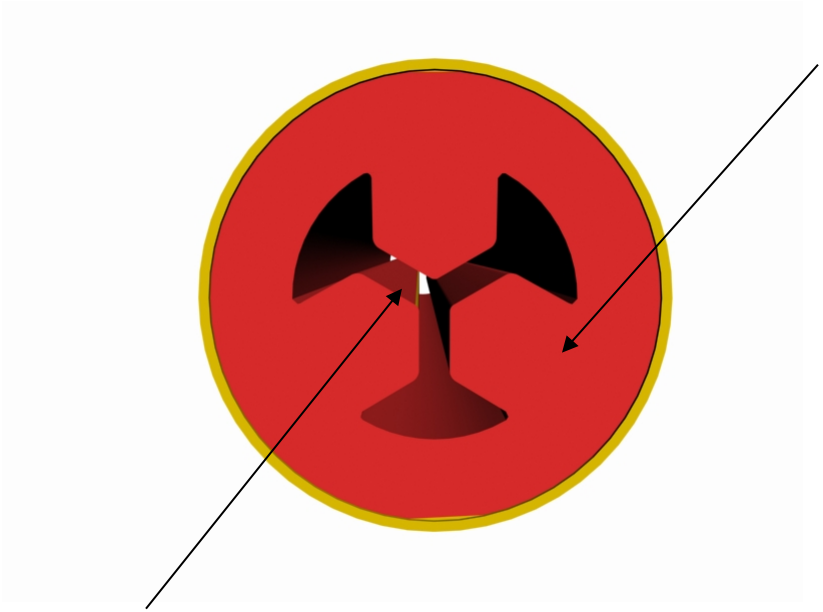
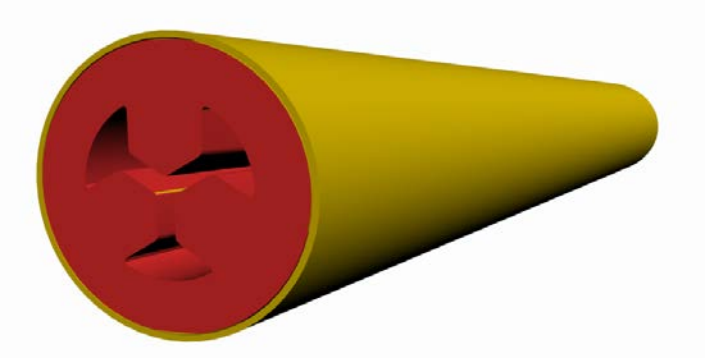


Tri-lobe

M28 Propellant: Nominal Composition

- 60% Nitrocellulose (NC)
- 23.8% Nitroglycerin (NG)
- 9.9% Triacetin
- 2.6% Dimethylphthalate
- 2.0% Pb Stearate
- 1.7% 2-Nitrodiphenylamine (2-NDPA)



Inhibitor Layer

- 70-74% Cellulose Acetate
- 26-30% Dimethylphthalate

M28 Rocket Motor Propellant – Test Objectives

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- **Objective 1** - *Following the pre-determined initial feed and ramp up plans, demonstrate the maximum size of an M28 propellant grain increment that can be fed to the Static Detonation Chamber (SDC) and Off-Gas Treatment (OGT) Systems without reaching (1) system parameter limits, (2) a feed limiting quantity of a constituent within the material, or (3) the TNTe limit*

- ***Objective 2*** - *Demonstrate the ability of the SDC and OGT Systems to process M28 propellant grain increments without incurring repeated temperature, pressure, or other alarms*

- **Objective 3** - *Demonstrate the ability of the SDC and OGT Systems to process M28 propellant grain increments and not be precluded from feeding by the generation of Carbon Monoxide above permit limit*

- **Objective 4** - *Determine the effects on various components throughout the SDC and OGT Systems that are uniquely associated with the processing of M28 propellant grain increments*

M28 Rocket Motor Propellant

- Each grain was cut into 4 pieces
- 80 total pieces fed
- Weights fed ranged from 1.24 pounds to 6.60 pounds with inhibitor
  - 1.16 pounds to 6.16 pounds Net Explosive Weight without inhibitor

M28 Rocket Motor Propellant

- Ramp up on March 2, 2015
  - Total number of pieces fed - 12
  - Total feed of 52.04 pounds
  - 10 second destruction timer

Feed Per Tray in Pounds			
Feed	**Pounds**	**Feed**	**Pounds**
1	**1.37**	**6**	**6.45**
2	**3.15**	**7**	**5.88**
3	**6.41**	**8**	**6.42**
4	**6.34**	**9**	**6.39**
5	**6.38**	**10**	**3.25**

M28 Rocket Motor Propellant

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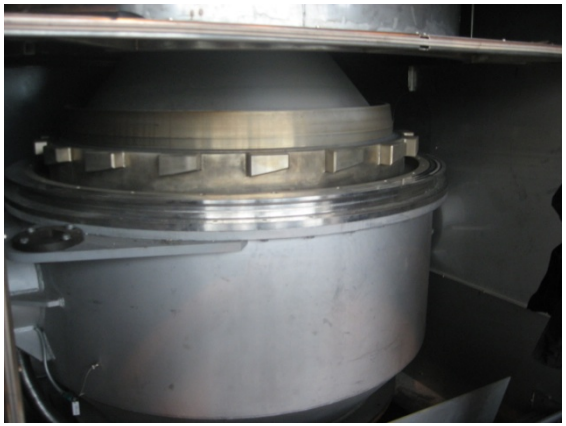
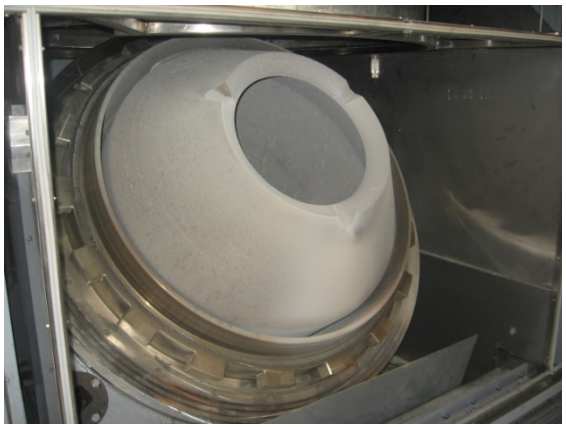
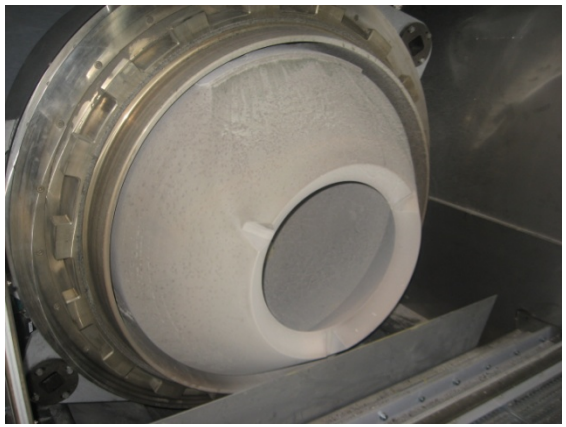
- Maximum Parameters Observed During Ramp Up
  - Chamber Pressure: 24.36 psi
  - Thermal Oxidizer Pressure: 0.058 psi
  - Thermal Oxidizer Temperature: 1890°F
  - Temperature of Off-Gas Piping: 625.91°F
  - Maximum *Carbon Monoxide* instantaneous: 3.52 parts per million volume







M28 Rocket Motor Propellant

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- Test Feed on Day 1, March 3, 2015
  - 5.71 pounds to 6.55 pounds
  - Total feed 113.8 pounds
  - 10 minute destruction timer

Feed Per Tray in Pounds			
Feed	Pounds	Feed	Pounds
1	6.44	10	6.37
2	6.35	11	6.49
3	5.71	12	6.48
4	6.26	13	6.47
5	6.37	14	5.87
6	6.57	15	6.55
7	6.43	16	6.29
8	6.34	17	6.47
9	5.91	18	6.43

M28 Rocket Motor Propellant

- **Maximum Parameters Observed During Test 1**
  - **Chamber Pressure: 11.95 psi**
  - **Thermal Oxidizer Pressure: 0.064 psi**
  - **Thermal Oxidizer Temperature: 1892°F**
  - **Temperature of Off-Gas Piping: 629.9°F**
  - **Maximum Carbon Monoxide instantaneous: 4.27 ppmv**

M28 Rocket Motor Propellant

- Test Feed on Day 2, March 4, 2015
  - 3.19 pounds to 6.60 pounds
  - Total feed of 161.64 pounds
  - 6 minute destruction timer

Feed Per Tray in Pounds				Feed Per Tray in Pounds			
Feed	Pounds	Feed	Pounds	Feed	Pounds	Feed	Pounds
1	6.48	9	6.35	17	6.48	25	6.43
2	5.91	10	3.19	18	5.74	26	6.47
3	6.46	11	3.34	19	6.57	27	6.39
4	6.29	12	6.53	20	5.59	28	6.60
5	6.45	13	5.91	21	6.48	29	4.46
6	640	14	6.49	22	6.46		
7	6.01	15	6.34	23	6.37		
8	6.31	16	6.27	24	5.86		

M28 Rocket Motor Propellant

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- Maximum Parameters Observed During Test 2
  - Chamber Pressure: 10.33 psi
  - Thermal Oxidizer Pressure: 0.063 psi
  - Thermal Oxidizer Temperature: 1889°F
  - Temperature of Off-Gas Piping: 638°F
  - Maximum Carbon Monoxide instantaneous: 5.15 ppmv

Inside of Detonation chamber after Test 2
(Pipe sections added for weight)

M28 Rocket Motor Propellant – Processing Results

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- **Objective 1** - *Following the pre-determined initial feed and ramp up plans, demonstrate the maximum size of an M28 propellant grain increment that can be fed to the Static Detonation Chamber (SDC) and Off-Gas Treatment (OGT) Systems without reaching (1) system parameter limits, (2) a feed limiting quantity of a constituent within the material, or (3) the TNTe limit*

- Test Results: Feed of the M28 propellant grain increments was demonstrated during the ramp-up period at a maximum charge of 6.16 pounds NEW/feed event, just below the 6.61 pounds NEW/feed event TNTe limit

- **Objective 2** - *Demonstrate the ability of the SDC and OGT Systems to process M28 propellant grain increments without incurring repeated temperature, pressure, or other alarms*

- Test Result: Feed occurred without generating any alarms

M28 Rocket Motor Propellant – Processing Results

- **Objective 3** - *Demonstrate the ability of the Static Detonation Chamber (SDC) and Off-Gas Treatment (OGT) Systems to process M28 propellant grain increments and not be precluded from feeding by the generation of Carbon Monoxide (CO) above the permit limit*

- **Test Results**: Generation of CO above the permit limit during a feed event did not occur
  - The highest CO value was 5.15 ppmv that occurred during Run 2
  - The permit limit is 100 ppm

- **Objective 4** - Determine the effects on various components throughout the SDC and OGT Systems that are uniquely associated with the processing of M28 propellant grain increments

- **Test Results**: No abnormal effects were incurred for the SDC or OGT Systems

M28 Rocket Motor Propellant

- Preliminary Emissions Data for Test 1, March 3, 2015
  - Total CDD/CDF - 0.017 ng-TEQ/dscm@7% O2 (Permit Limit - 0.20)
  - Chloride Equivalents -1.06 ppmv@7% O2 (permit Limit – 21)
  - Particulates - .00068 gr/dscf @7% O2 (permit limit – 0.013)
  - Arsenic, Beryllium and Chromium – 5.41 ug/dscm@7% O2 (permit limit – 23)
  - Cadmium and Lead – 2.19 ug/dscm@7% O2 (permit limit – 10)
  - Mercury – 9.83 E-07 ug/dscm@7% O2 (permit limit – 8.1)
  - No Energetics Detected
  - Highest Semi-Volatile Organic Detected – Benzoic Acid at 1.17 E-05 g/s (no permit limits for Semi-Volatile Organics)
  - Highest Volatile Organic Detected – Chloromethane at 5.82 E-05 g/s (no permit limits for Volatile Organics)

dscf: dry standard cubic foot
dscm: dry standard cubic meter
ppm: parts per million

M28 Rocket Motor Propellant

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- Preliminary Emissions Data for Test 2, March 4, 2015
  - Total CDD/CDF - 0.019 ng-TEQ/dscm@7% O2 (permit Limit - 0.20)
  - Chloride Equivalents -0.94 ppmv@7% O2 (permit Limit – 21)
  - Particulates - .00059 gr/dscf @7% O2 (permit limit – 0.013)
  - Arsenic, Beryllium and Chromium – 4.51 ug/dscm@7% O2 (permit limit – 23)
  - Cadmium and Lead – 2.84 ug/dscm@7% O2 (permit limit – 10)
  - Mercury – 9.52 E-07 ug/dscm@7% O2 (permit limit – 8.1)
  - No Energetics Detected
  - Highest Semi-Volatile Organic Detected – Benzoic Acid at 1.43 E-05 g/s (no permit limit for Semi-Volatile Organics)
  - Highest Volatile Organic Detected – Bromomethane at 1.27 E-05 g/s (no permit limit for Volatile Organics)

dscf: dry standard cubic foot
dscm: dry standard cubic meter
ppm: parts per million

Testing Method Protocols

US Environmental Protection Agency (EPA) Method 4 - Moisture for the isokinetic sampling trains,

- SW-846 Method 0010 - Semivolatile organic compound emissions,
- SW-846 Method 0023A - Total dioxin/furan emissions,
- SW-846 Method 0031 - Volatile organic compound emissions,
- US EPA Method 5/26A - Acid gases and particulate matter emissions,
- US EPA Method 29 - Metal emissions, and
- US EPA Modified Method 5 - Energetic emissions - also called STEM

M28 Rocket Motor Propellant

- Path Forward
  - Pursue Testing with increasing NEW increments up to an entire M67 rocket motor