Thermal Decomposition in a Coextrusion Process

14th Continuous Mixer and Extruder User's Group Meeting
11-12 October 2006

C. Gonzalez

S. E. Prickett

R.S. Muscato

J.J. Baker

S.L. Brown

Outline

- Background
- Colayered Manufacturing Process
- Processing Run Graphics
- Thermal Decomposition Pictures
- Findings
- Failure Mechanism
- Recommendations

Background

1st Thermal Decomposition

- Experienced a thermal decomposition in a 40-mm TSE processing run on 8/12/04
- No personnel injuries or equipment damages
- Investigation team found two main causes for decomposition
  - improper selection of die hardware that resulted in a diverging flow into a large volume between the screws and the die entrance
  - combination of low throughput and material rheology that created thermal energy buildup
- Incorporated investigation recommendations

Progress Since

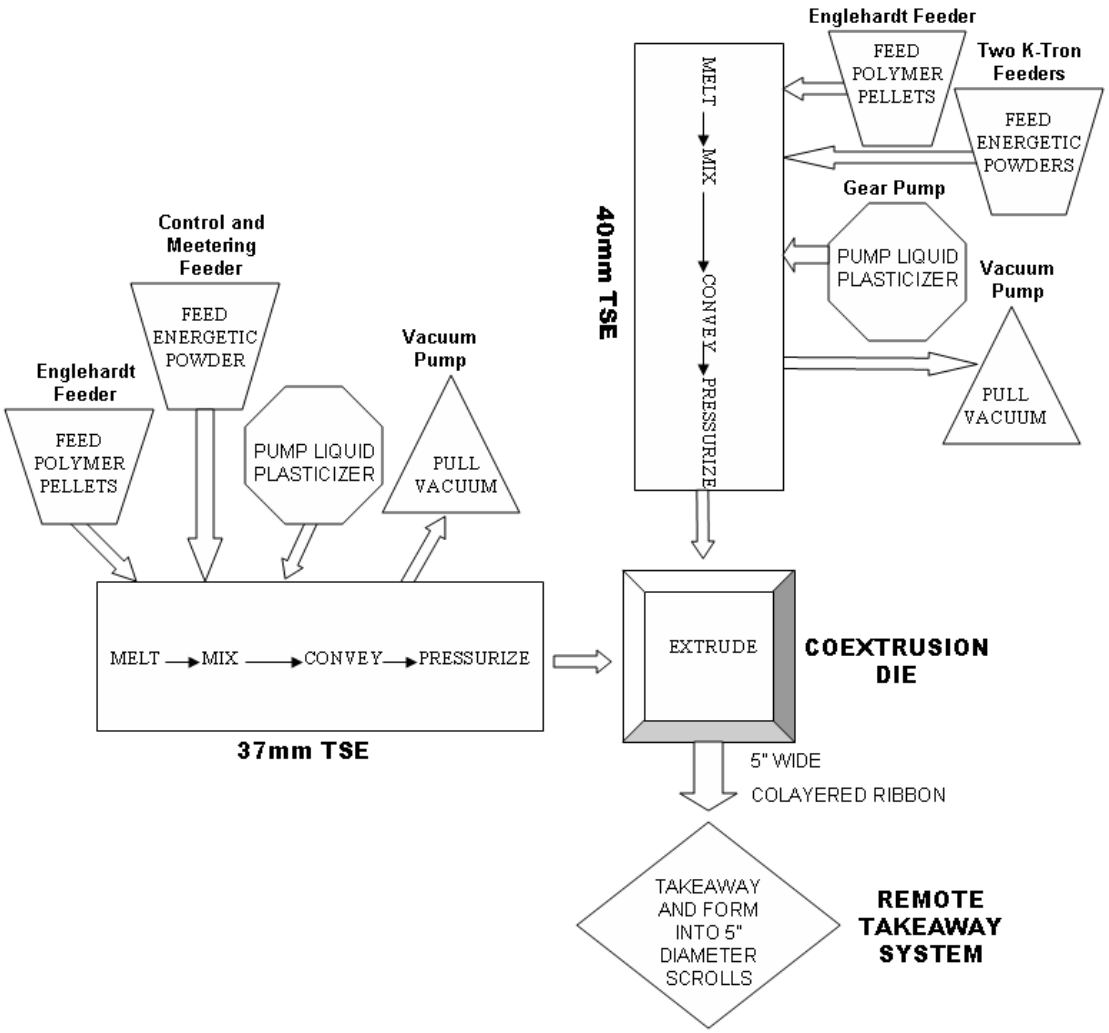
1st Thermal Decomposition

- Lab analysis showed low content of stabilizer in the A/F
- Added additional stabilizers to A/F to increase the decomposition temperature and continue processing efforts with the propellant simulant
- Focused on reaching an adequate vacuum level early in the process to remove any impurities
- Conducted multiple safe processing trials with the 40-mm TSE and the coextrusion die to test/commission the Take-Away-System
- Processed the simulant with the 37-mm TSE to determine screw/barrel configurations and characterize the process parameters

2nd Thermal Decomposition

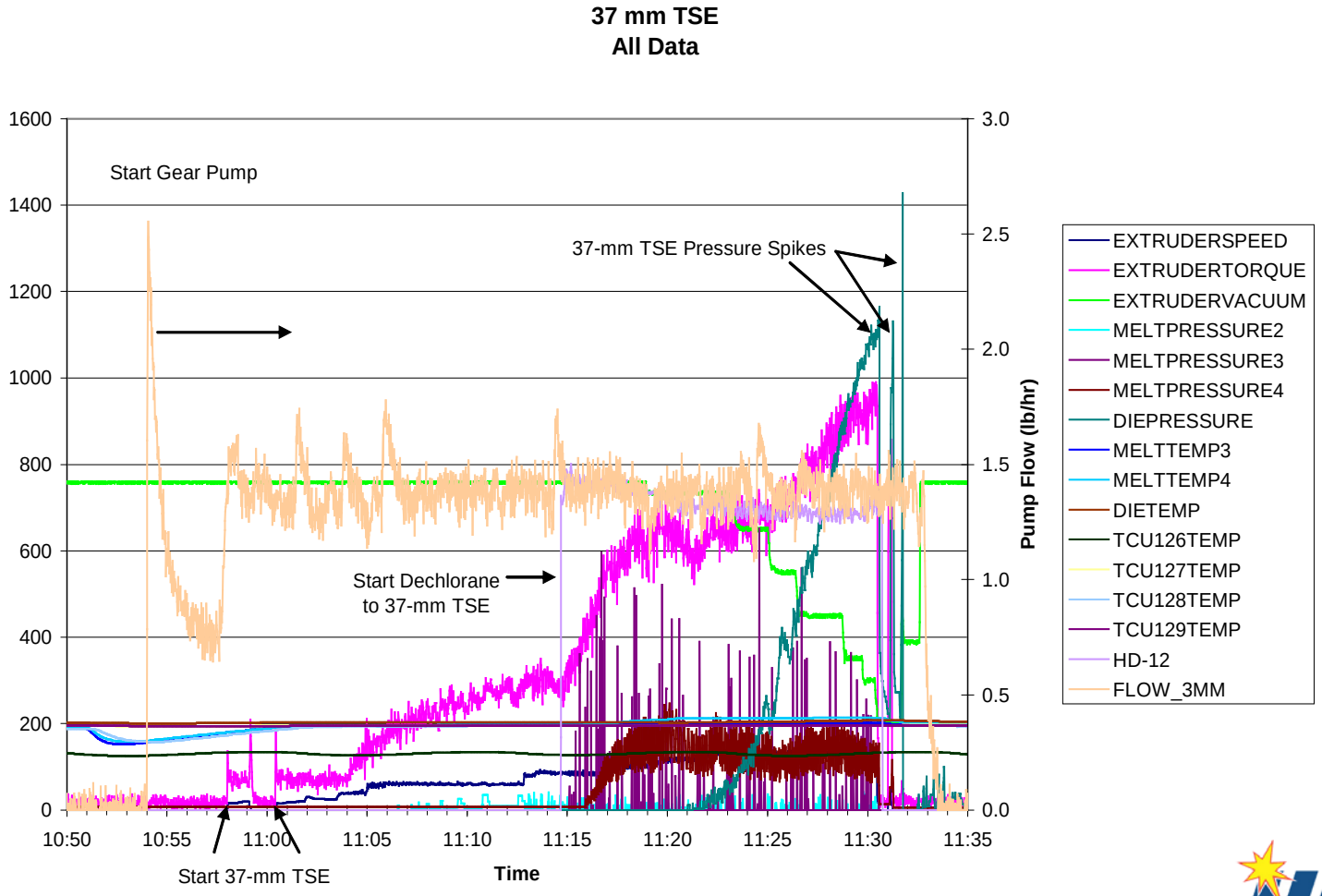
- Experienced a 2nd thermal decomposition in our first integrated coextrusion processing trial on 4/27/06.
- No personnel injuries or equipment damages.
- The decomposition occurred during ramp-up while both extruders were running.
- The thermal decomposition was isolated within the 37-mm TSE with decomposition products exiting through the vacuum port.

Colayered Manufacturing Process



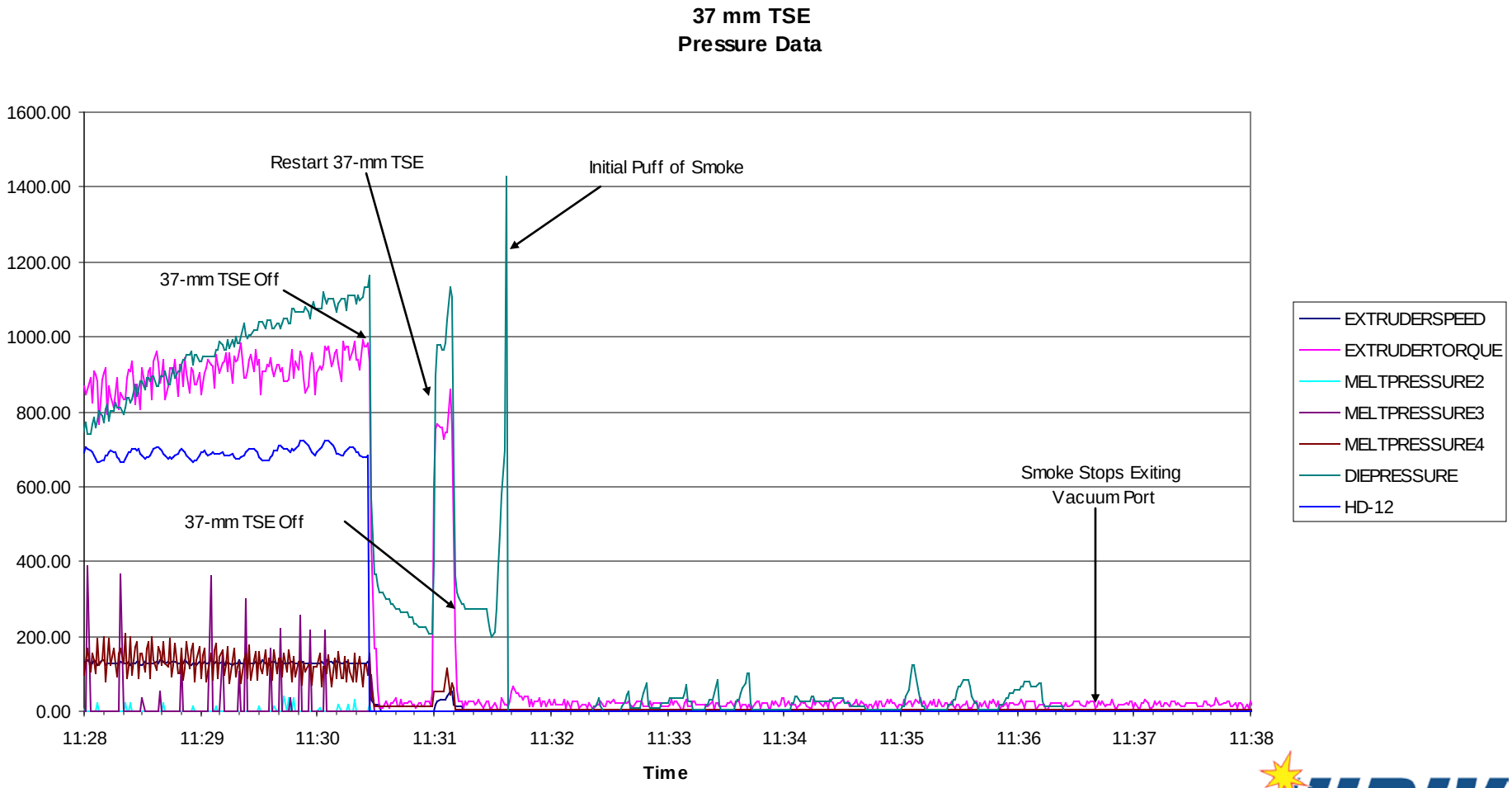
37-mm TSE Ramp-up

4/27/2006



37-mm TSE Pressure Responses

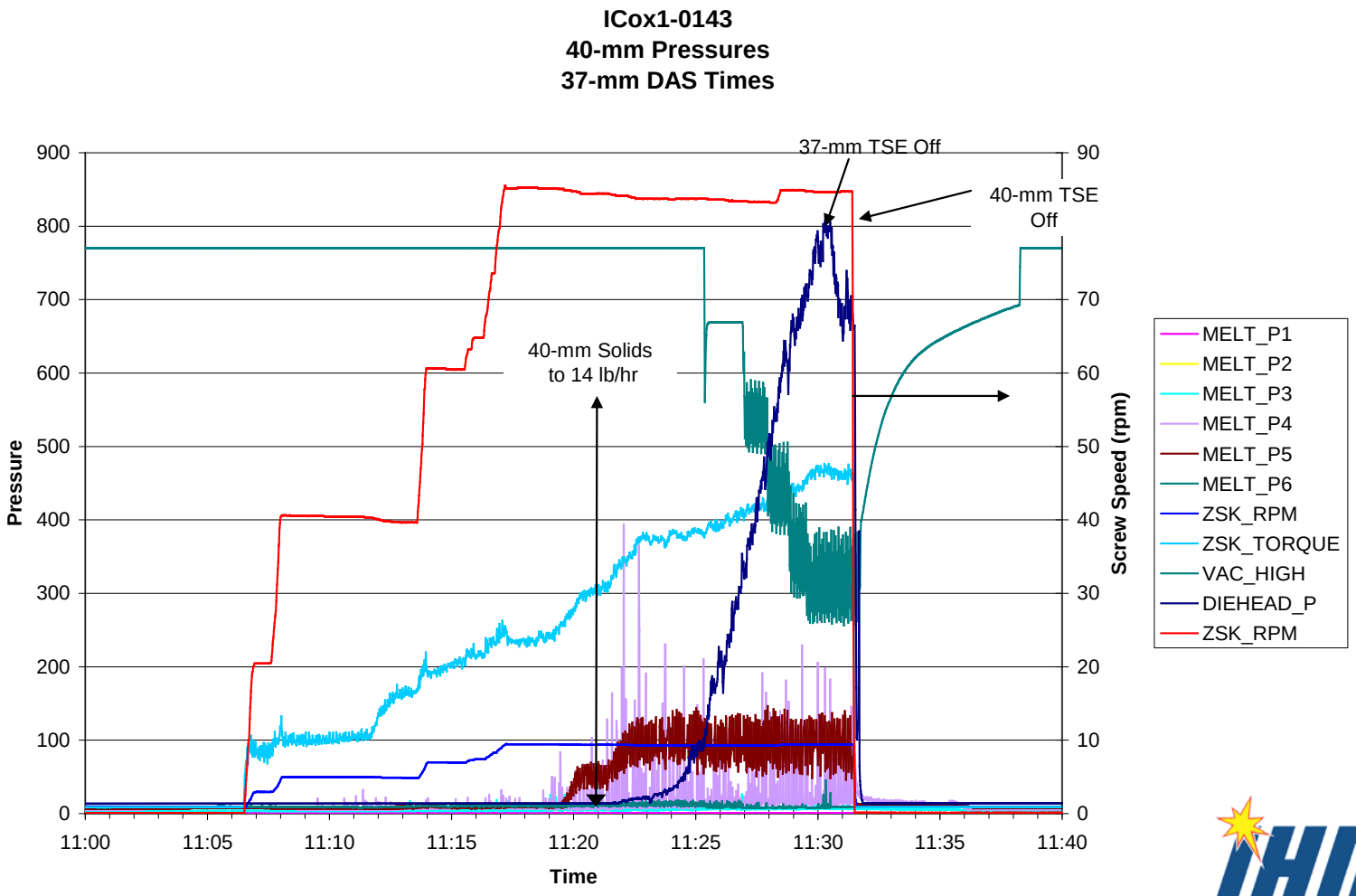
4/27/2006



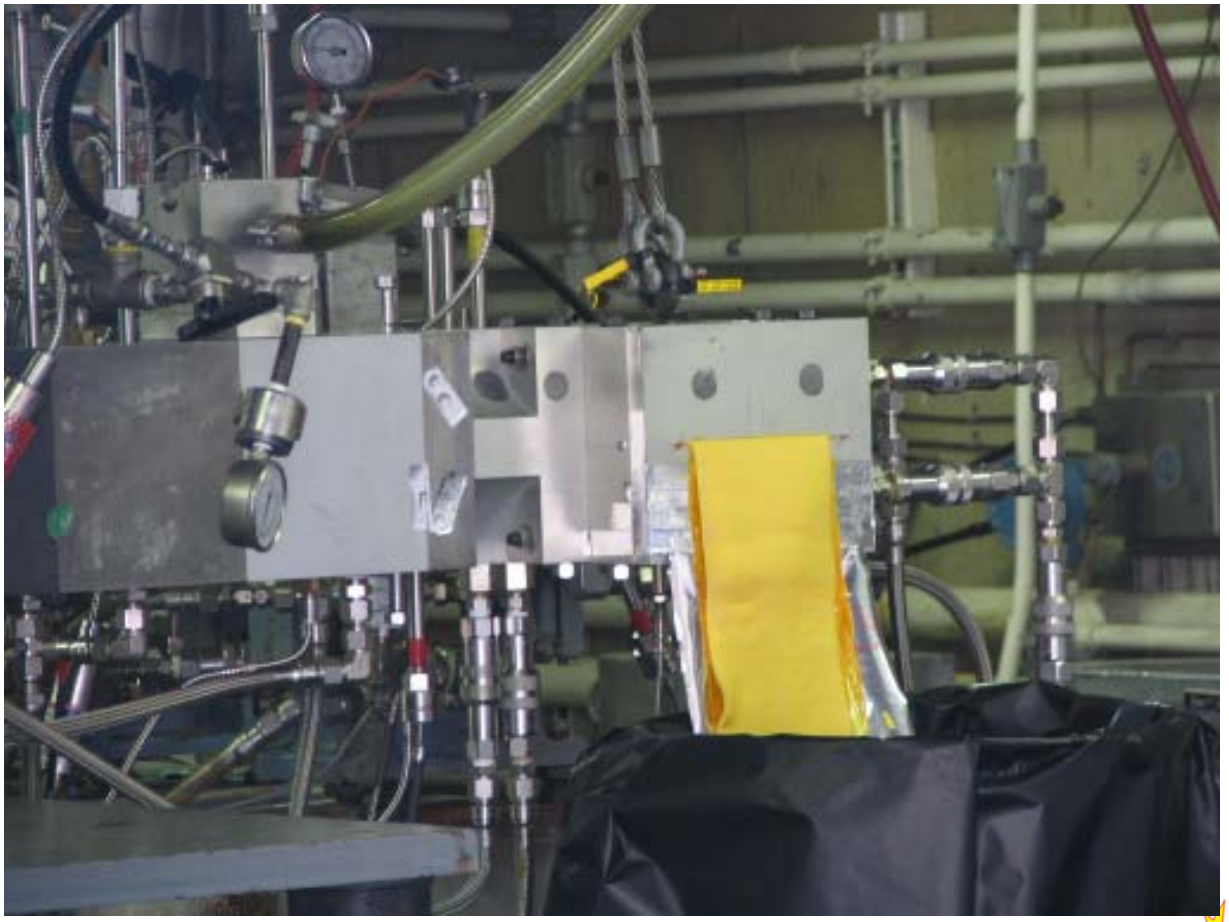
DoD ENERGETICS CENTER
Excellence for the Warfighter

40-mm TSE Ramp-up

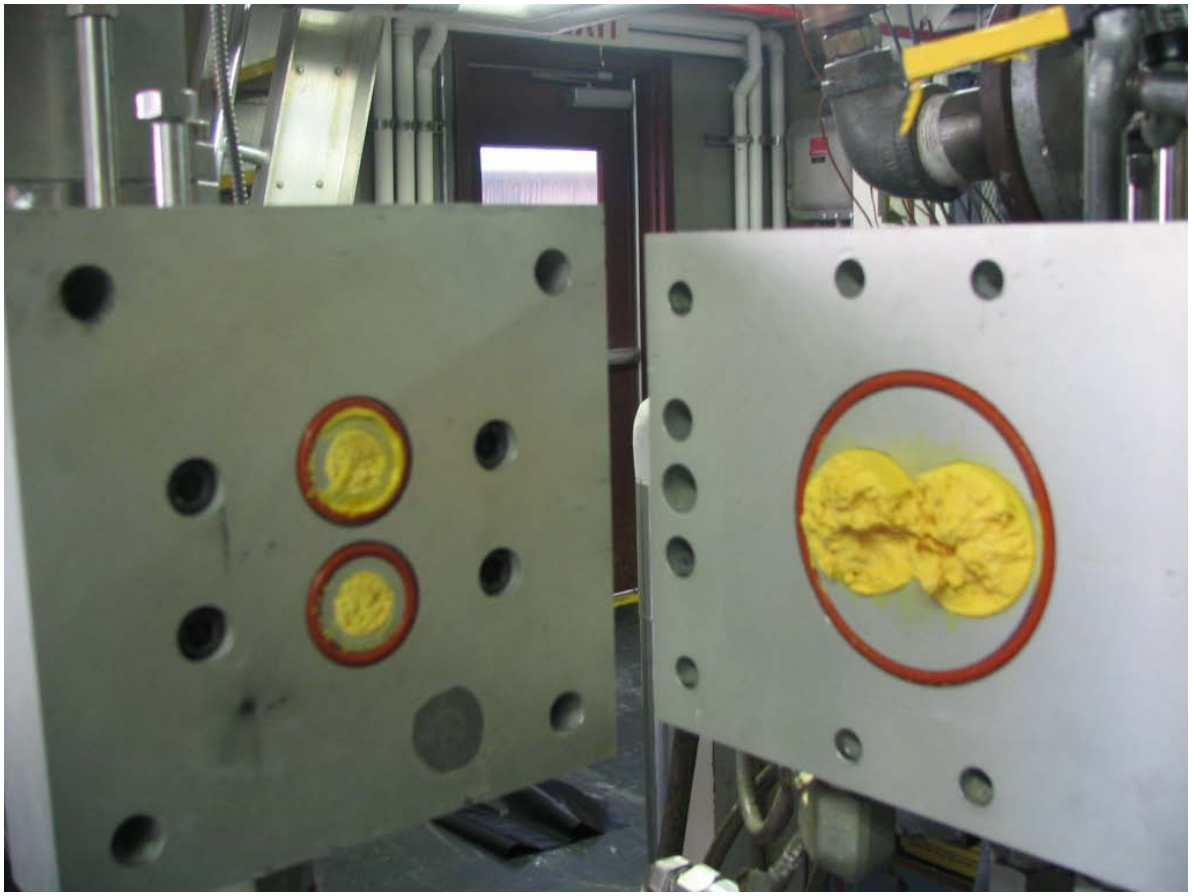
4/27/2006



Thermal Decomposition Pictures

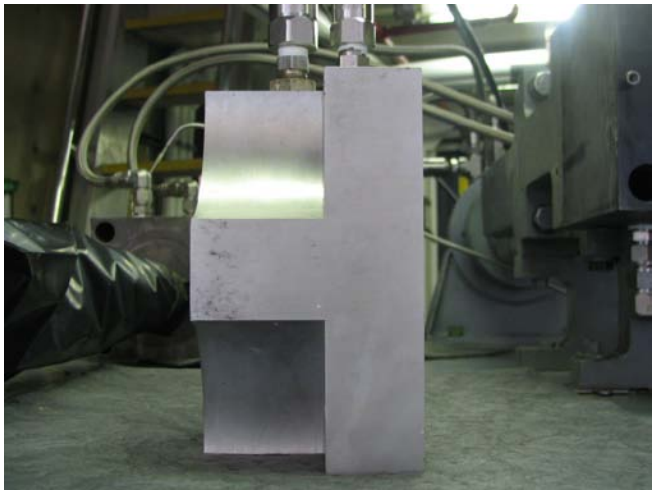


Thermal Decomposition Pictures

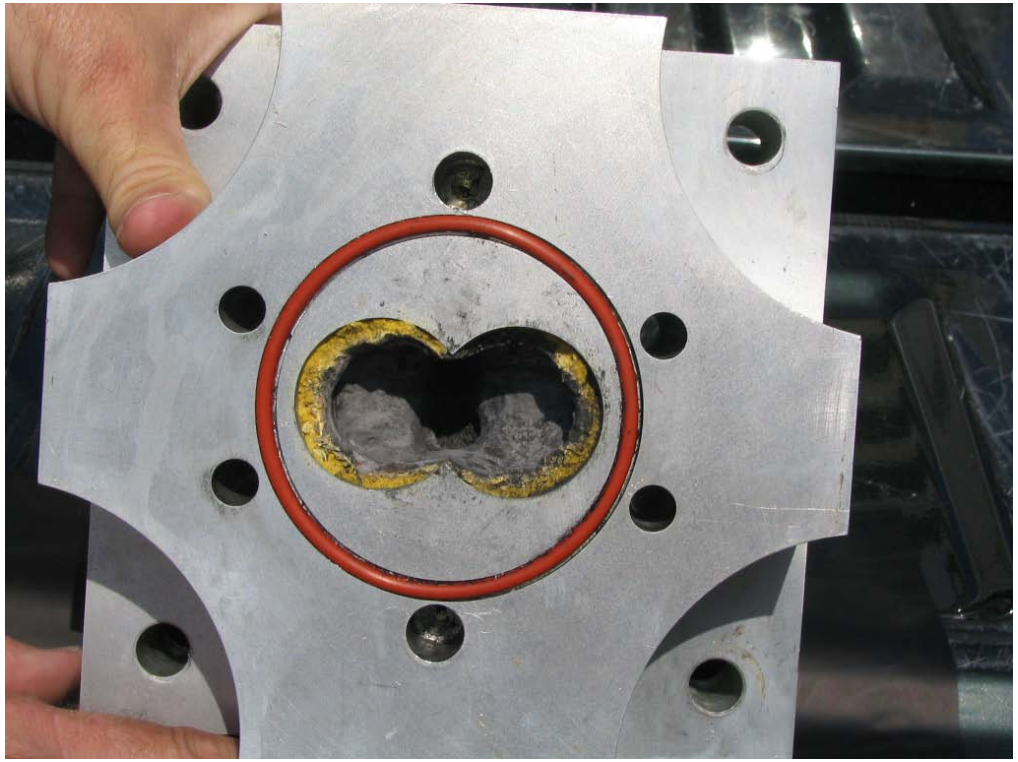


Coextrusion Die Removed

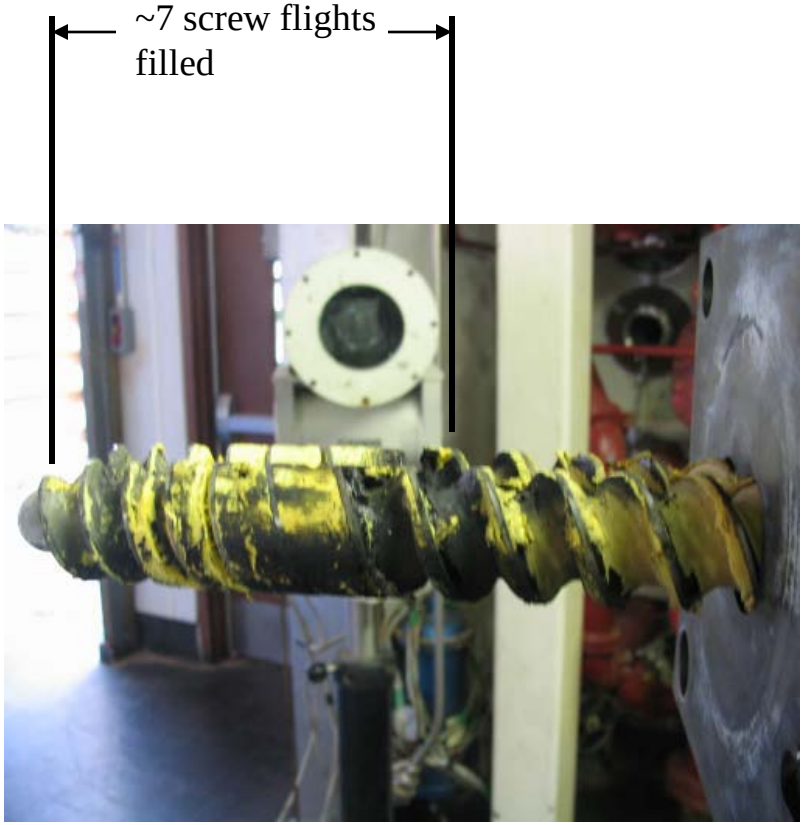
Thermal Decomposition Pictures



Material Flow



Thermal Decomposition Pictures

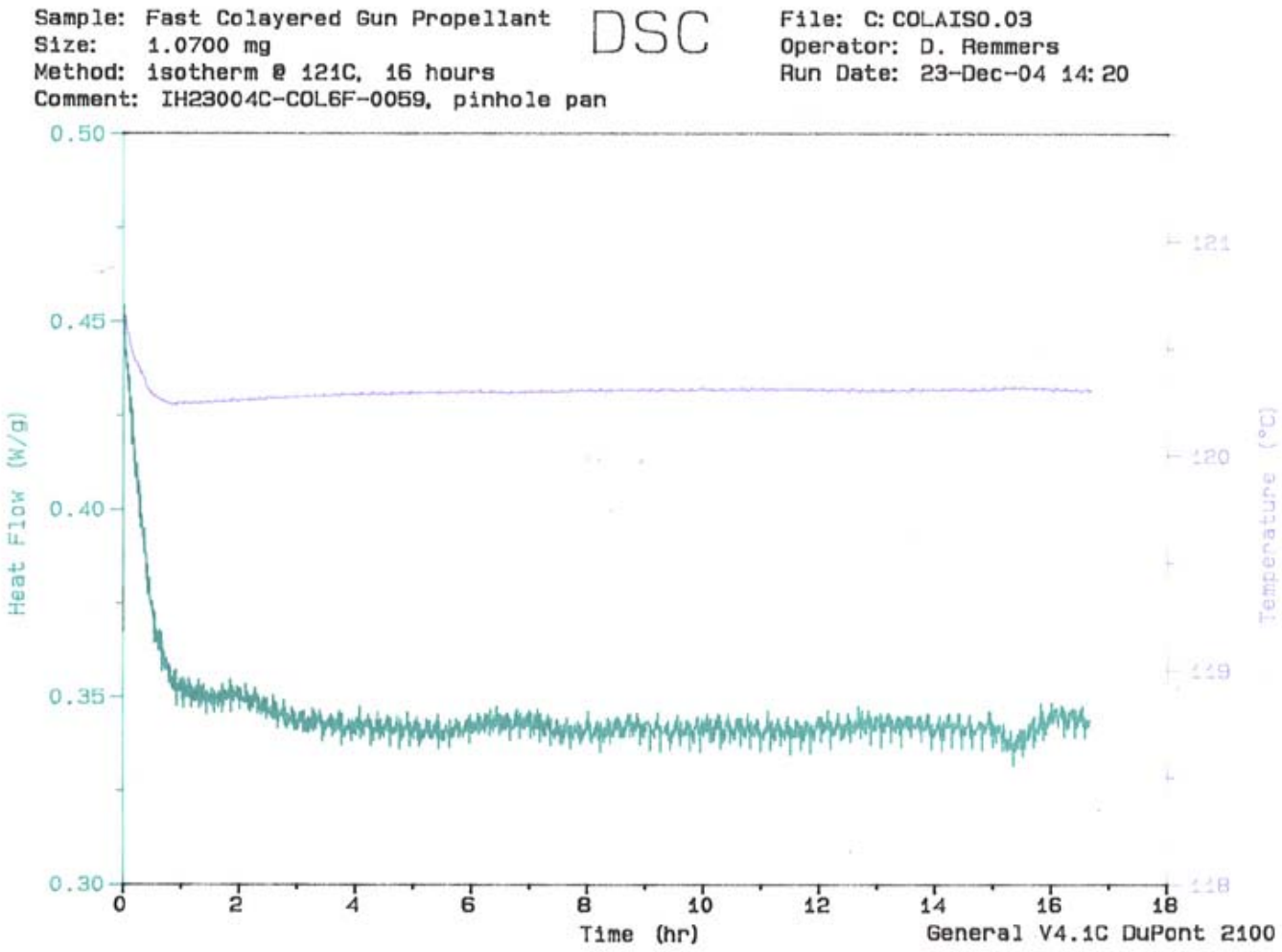


One plate and one barrel removed

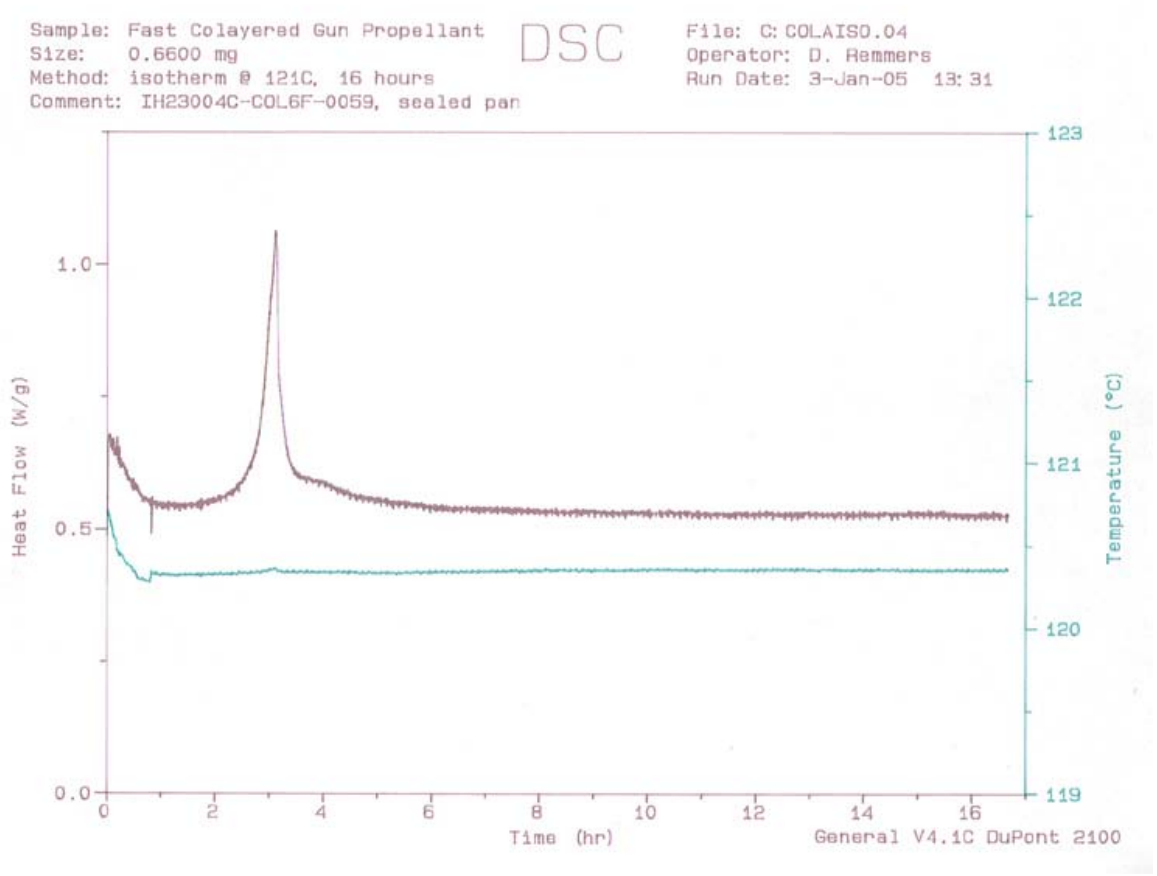
Findings

- Approximate rheological comparisons between Colayered Propellant and Simulant extruded with a 2-in Press shows significant differences in surface finish. Simulant shows rebar surface finish vs. a smooth finish on the Slow Burning Propellant.
- FEM simulations results with Slow Propellant Rheology showed minimum temperature rise in the die region
- DSC and ARC testing conducted showed;
  - Differences in conducting DSC testing in a pin-hole versus sealed pan,
  - Increase in DSC onset temperatures by adding additional stabilizer to the A/F and,
  - Correlation between "bumps" in isothermal DSC testing and onset temperatures in ARC testing.

Pin Hole Pan DSC



Sealed Pan DSC

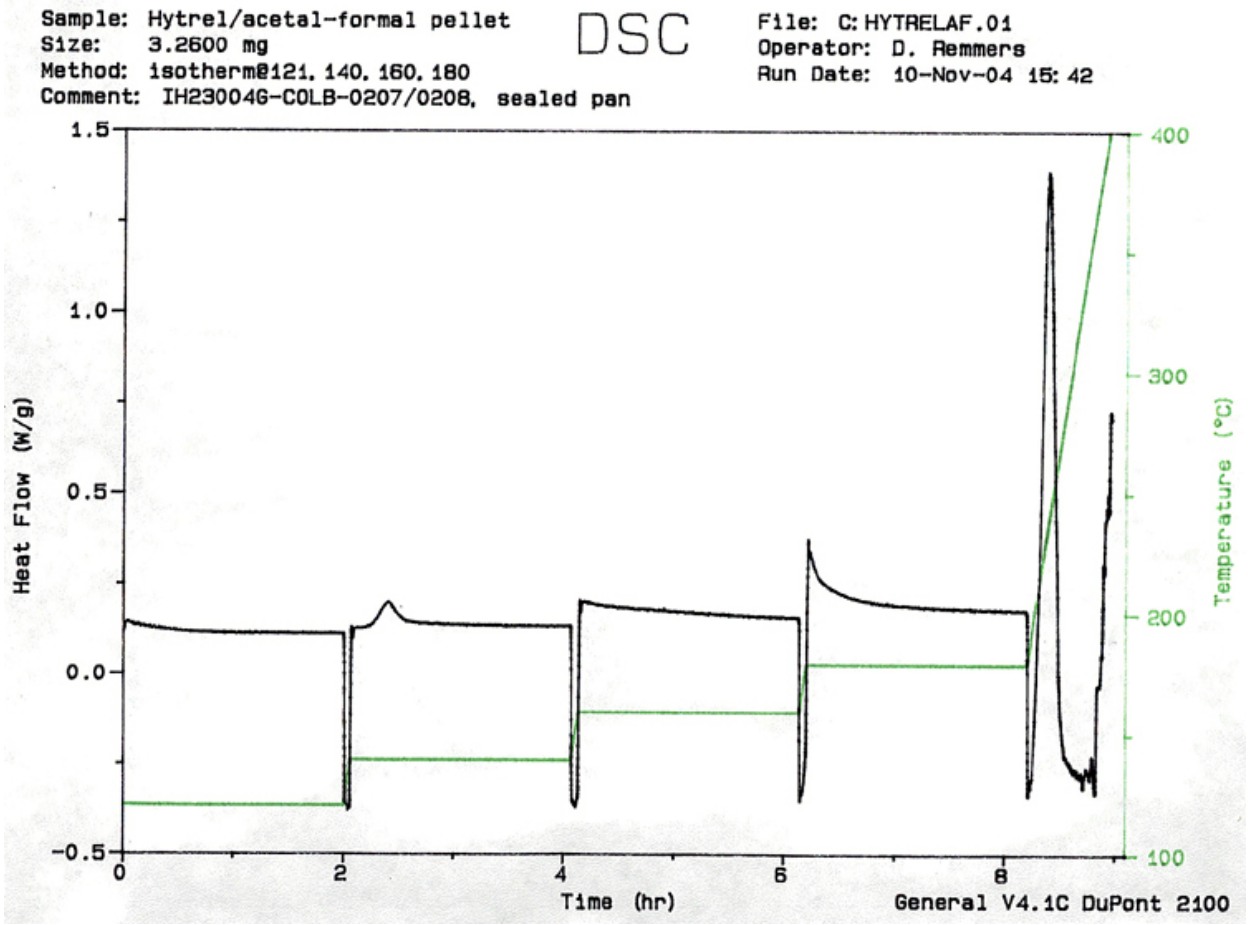


Fast Co-Layered Gun Propellant, 16 hour Isothermal DSC @ 121ºC

Sealed Pan

Original Binder Pellet

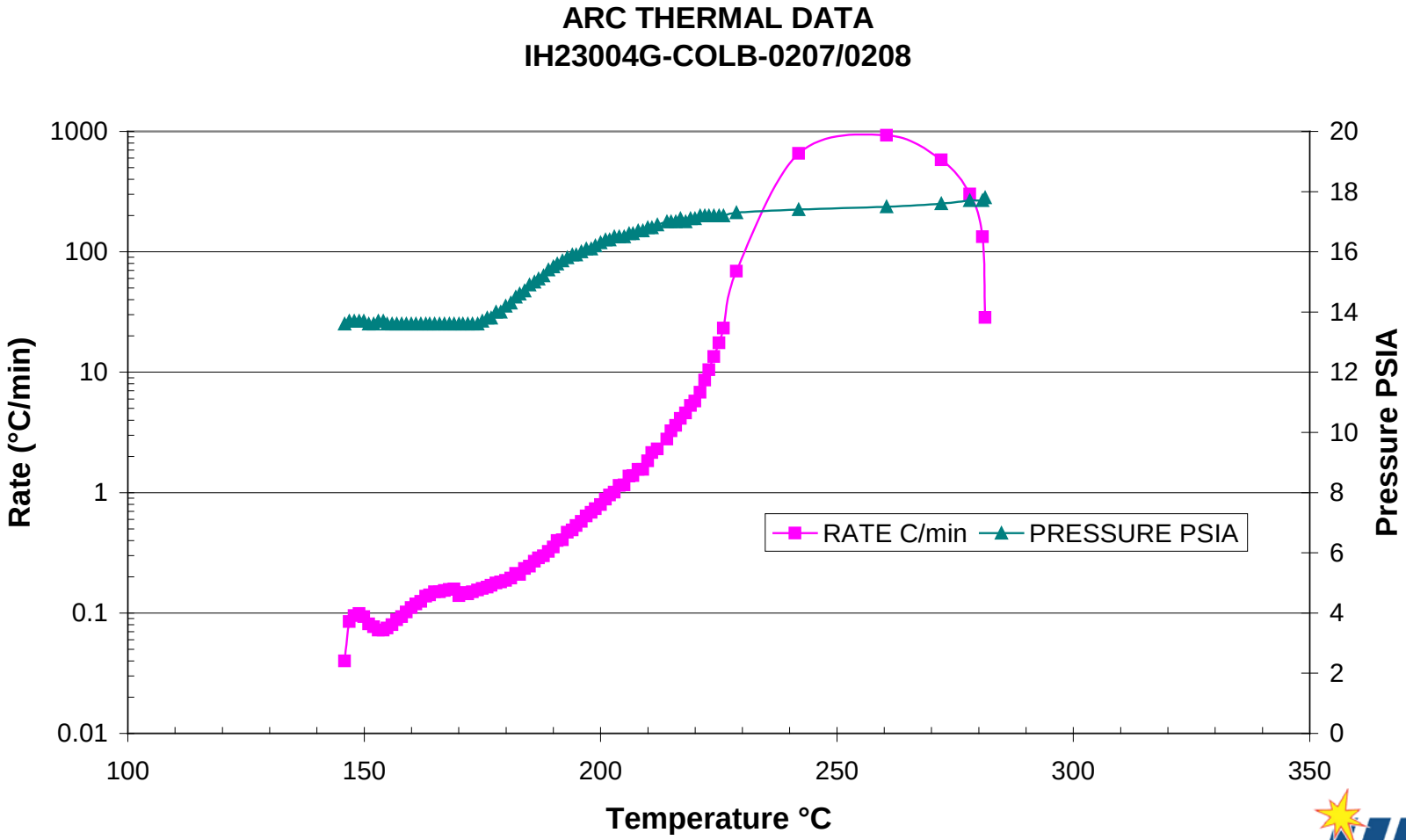
(No additional stabilizer)



Isothermal Step DSC: 121ºC, 140ºC, 160ºC, 180ºC, to Decomposition

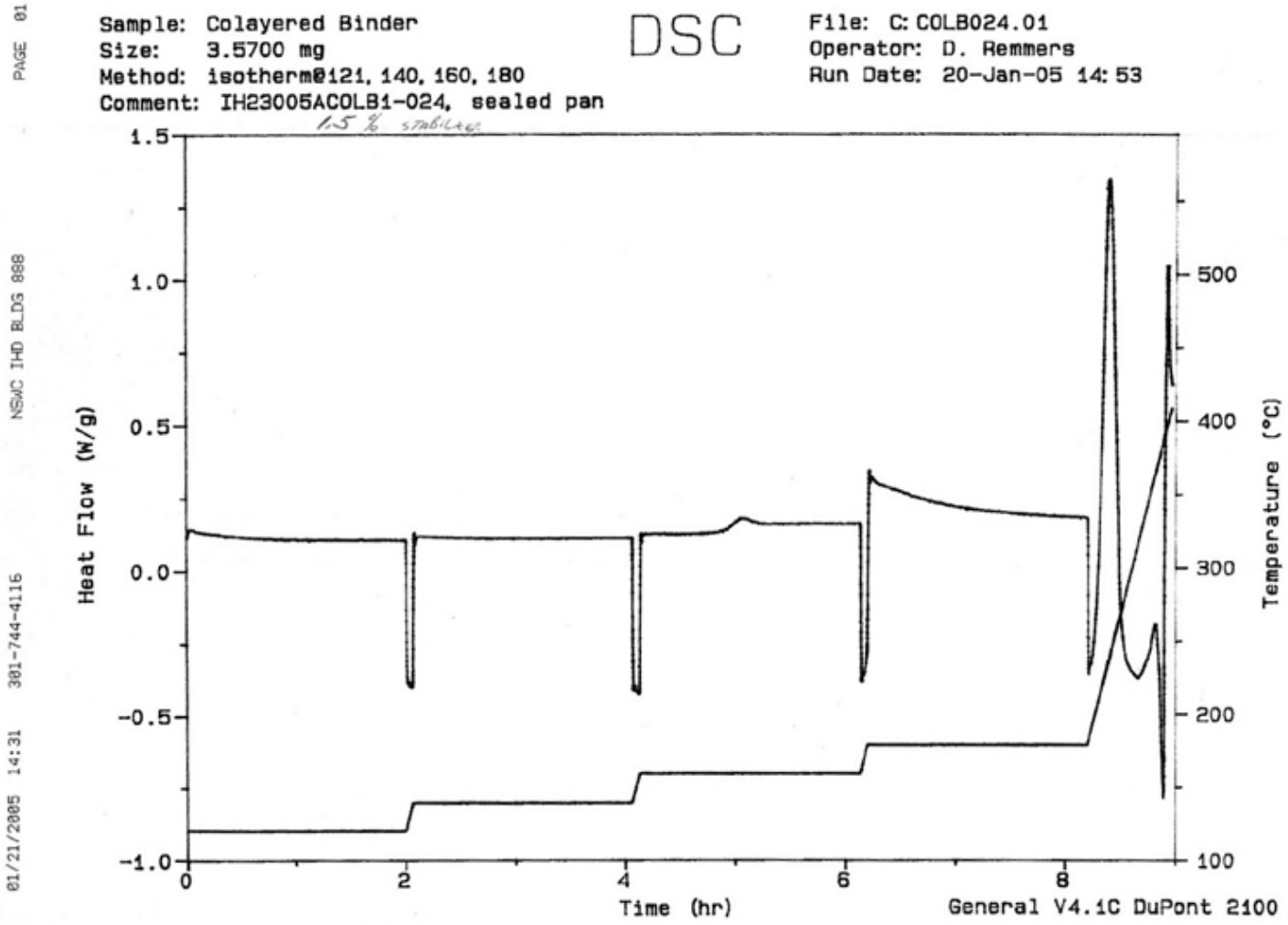
Original Binder Pellet

(No additional stabilizer)



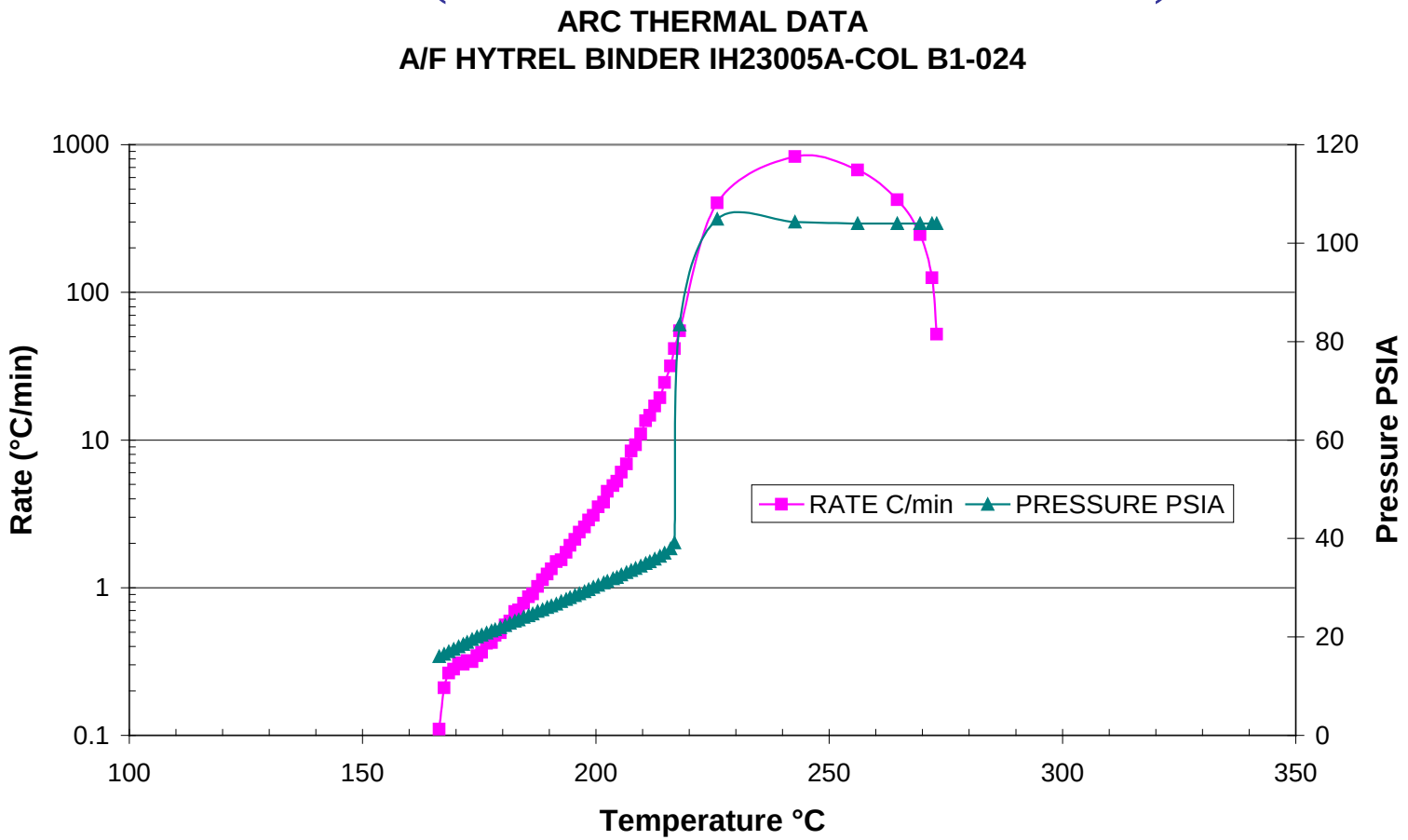
Binder Pellet

(With additional stabilizer)



Binder Pellet

(With additional stabilizer)



Failure Mechanism

- The two most significant factors were
  - Rheological characteristics of the simulant propellant
  - Material stagnation and heat accumulation between the screws tips and die entrance during ramp-up
- Temperature increased to the point where the A/F started to decompose
- Since the simulant is a poor heat conductor, the heat generated by the reaction could not dissipate causing a "chain reaction" where the temperature continued to rise and the entire formulation was consumed.

Recommendations

- Use a completely inert propellant formulation during the initial validation of the coextrusion process
- Use dried Hytrel® 8184
- During inert operations personnel should clear the processing bay until steady state conditions are reached
- If the TSE needs to be restarted, increase the speed of the screws slowly
- Reevaluate the use of Dechlorane Plus and other RDX simulants
- Improve die zone temperature measurement capability
- Incorporate the capability of monitoring material temperature about 1-inch from the tip of the screws