An Overview of Indian Head Division's Continuous Processing Capabilities and Projects

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Outline / Team Members

- Background
- Team Members
- IHDIV's Capabilities
  - Material Characterization Through Scale Up
- Current Projects
- Industry Survey
  - Request for Safety Protocol Information
- Summary

- <u>Key Team Members</u>
  - Richard Muscato
  - Suzanne Prickett
  - Chris Gonzalez
  - Wayne Thomas
  - Mark Williams
  - Woojae Lee
  - Ron Myers
  - Virginia Hintze

Rheological Characterization

Rheology

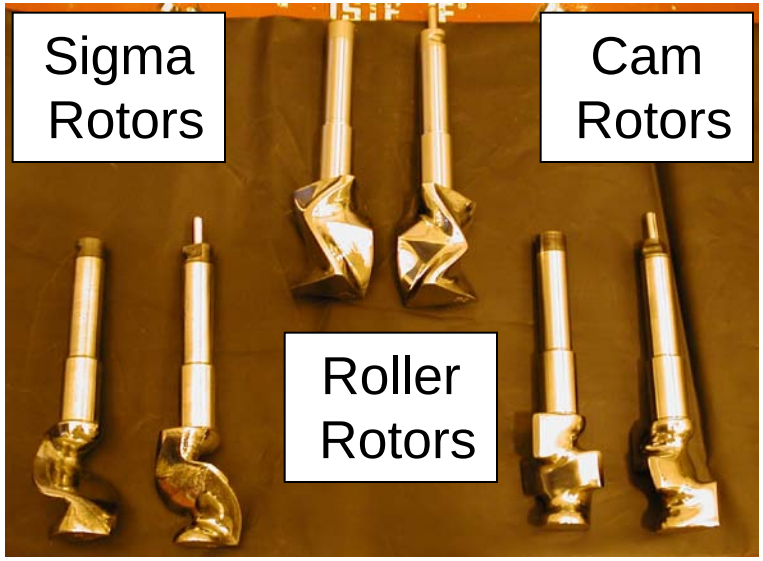
- The Study of Flow and Deformation of Materials
  - Yield Stress
  - Viscoplasticisity
  - Shear Rate
  - Wall Slip
  - Activation Energy
- Hershel Bulkley Constitutive Equation
  ($\tau_w = \tau_o + m_o\gamma_w^n$)
- Necessary for Die Design and TSE Modeling

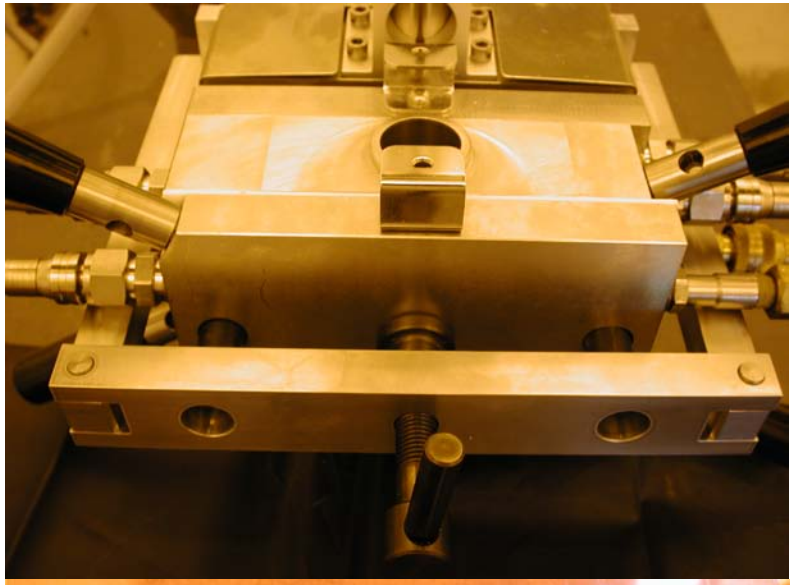
Capabilities

- Torque Rheometer
- 11 Capillary Dies Used in Conjunction with the 2" Vertical Press
- Adjustable Slit Die Rheometer Used with 40 mm TSE

Haake Torque Rheometer

Requires ~60 cm^3 Material
Sufficient Material for Micro-
  Closed Bomb Testing
Monitor Torque vs. Time
  Binder Melt
  Solids Incorporation

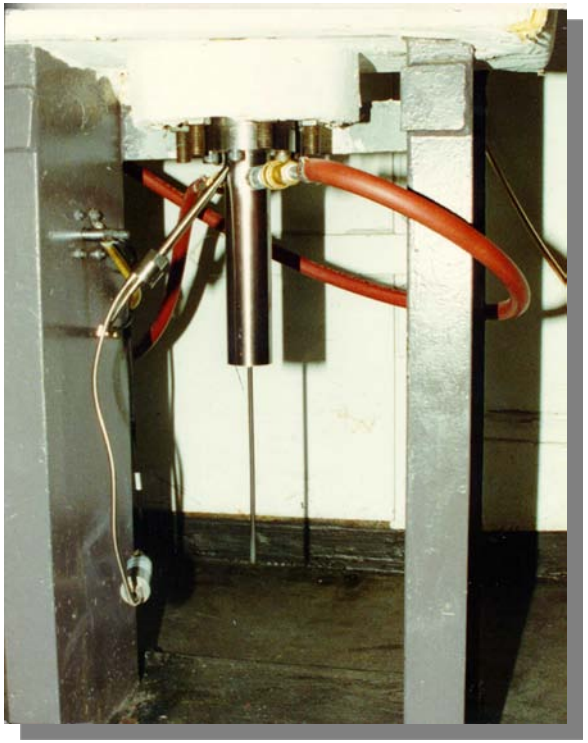


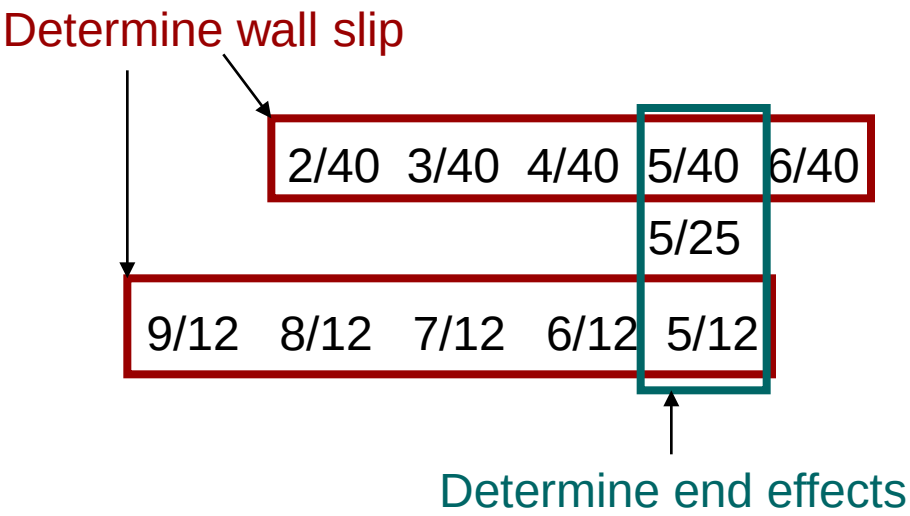


Capillary Dies w/2" Press

- Dies and Press Jacketed for Temperature Control (ambient to 270ºF)
- Automated Data Acquisition System

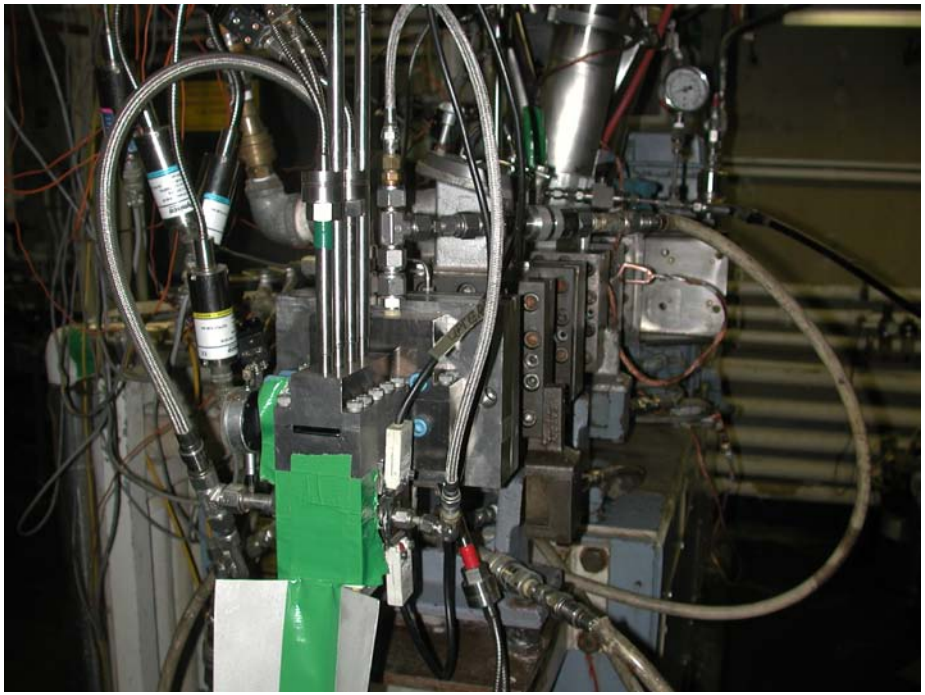
- Dies Instrumented with Dynisco Temperature/Pressure Transducer at Capillary Entrance
- Need ~ 4 – 10 Pounds of Material to Fully Characterize Rheological Behavior

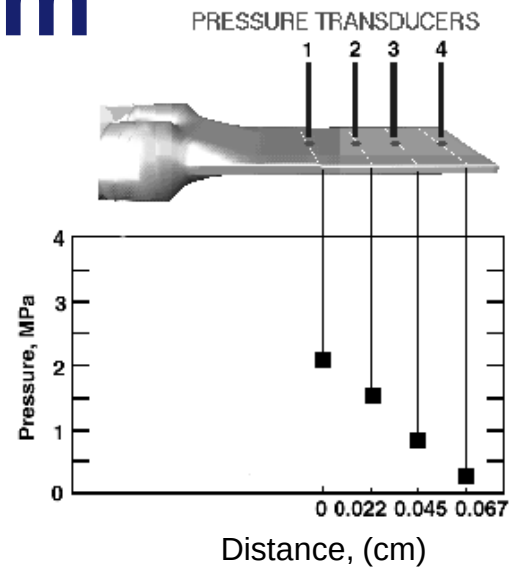




x/y: x = Die D, y = L/D

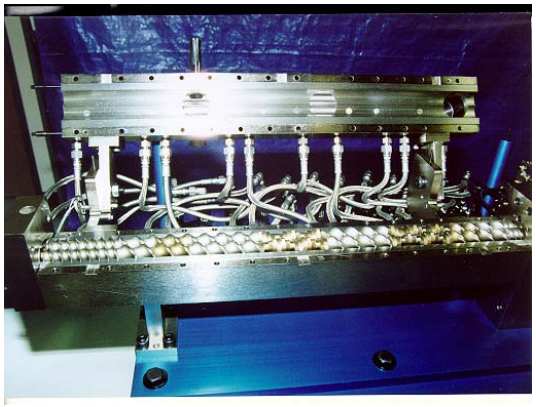
Adjustable Slit Die Rheometer Used with 40 mm

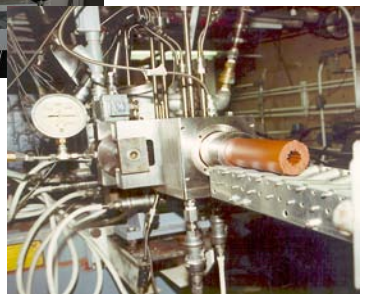


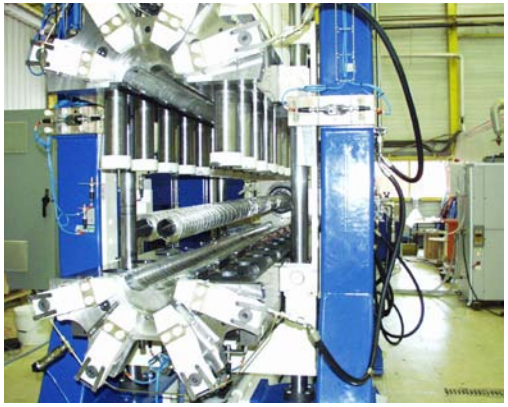


- Fixed gap width (W)
- Known volumetric flow rate (Q)
- Change gap height (H)
- Measure pressure, P(z)
- Determine apparent shear rate ($\dot{\gamma}_a$)
- pressure gradient ($\frac{\partial P}{\partial z}$)
- shear stress (τ_w)
- shear sensitivity index (n)
- Change throughput, Q, to determine wall slip

TSE vs. Batch (Horizontal Mixers)







20-mm – 5 lbs./hr.

37-mm and 40-mm – 50 lbs./hr.

88-mm – 300 lbs./hr.

Initial Formulation Evaluation
- Generate safety data
- Burning rate
- Physical & thermal properties

Evaluate Processing Conditions
- Optimize formulation
- Mix process validation

Scale-Up
- LRIP
- Full scale mfg

½ pint – 40 grams

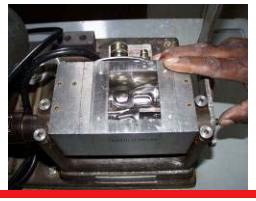
2 liter – 2 lbs.

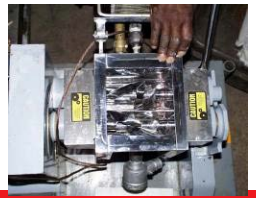
2-1/4 gal. – 8 lbs.

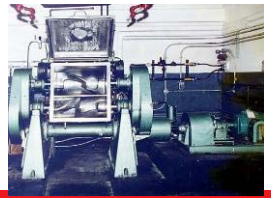
25 gal. – 100 lbs.

100 gal. – 350 lbs.

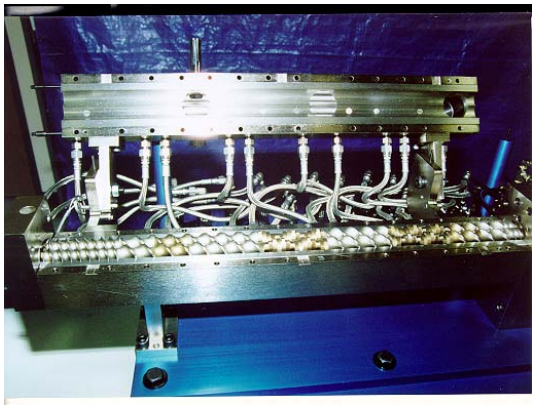
150 gal. – 660 lbs.

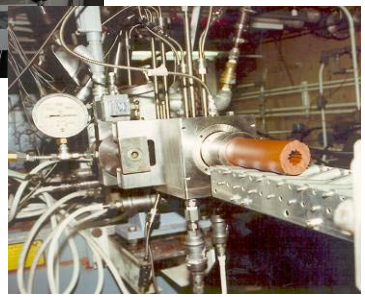






TSE vs. Batch (Vertical Mixers)





20-mm – 8 lbs./hr.

37-mm and 40-mm – 100 lbs./hr.

88-mm – 600 lbs./hr.

Initial Formulation Evaluation
- Generate safety data
- Burning rate
- Physical & thermal properties

Evaluate Processing Conditions
- Optimize formulation
- Mix process validation

Scale-Up
- LRIP
- Full scale mfg

1 pint – 1 lb.

1 gal. –10 lbs.

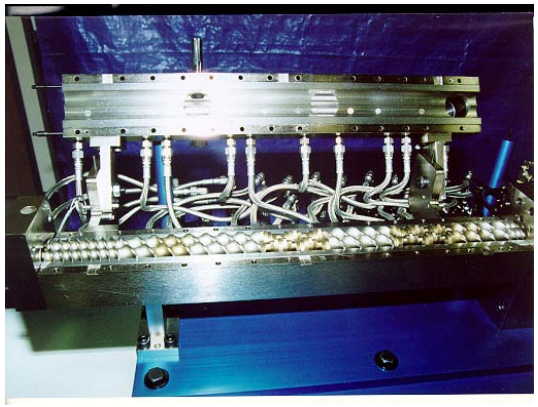
5 gal. – 50 lbs.

30 gal. – 200 lbs.

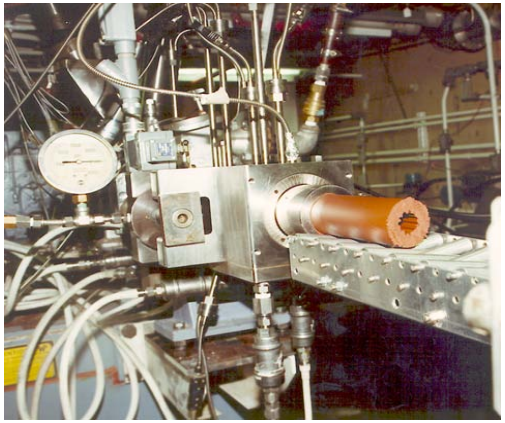
150 gal. – 1500 lbs.

420 gal. – 6000 lbs.

Scale-up for Granular/Stick



20-mm



37 40 mm

88-mm

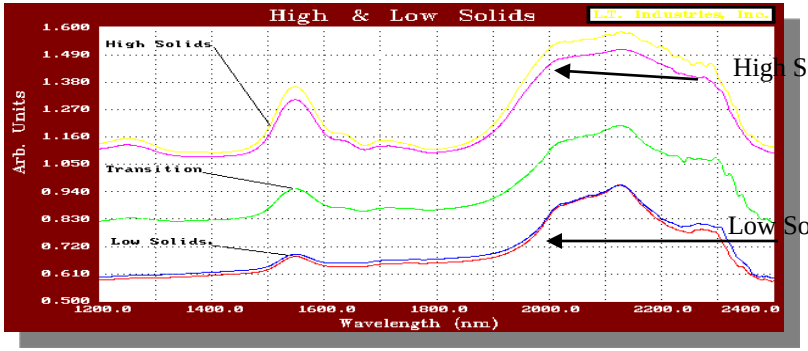
- Minimize use of expensive ingredients during ramp-up and ramp-down
- Ensure that consistent work/energy input is going into the propellant at each extruder

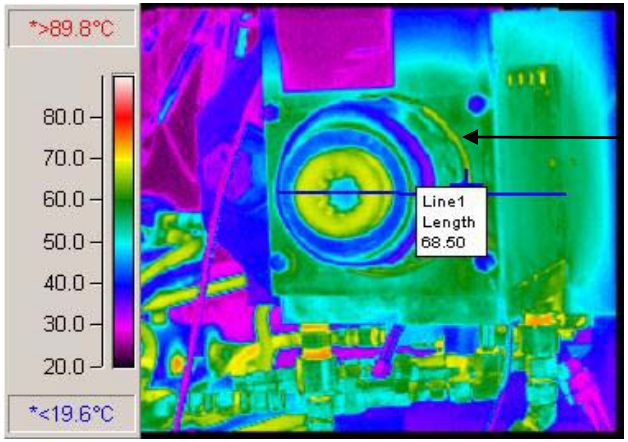
Current Projects

ID	Title	Purpose
1	Quality Control Diagnostic System	Capabilities Increase
2	Acoustic Monitoring System	Capabilities Increase
3	Vacuum Casting System	Capabilities Increase
4	Inline Cutter for Small Diameter Energetics	Capabilities Increase
5	DOD Surplused Explosives	Development
6	MK99 LOVA Manufacturing Demonstration in the 88mm TSE	Capabilities Increase and Demonstration
7	Flexible Manufacturing of Nitrogen Based Gun Propellants	Development and Demonstration
8	TSE Material Characterization (Modeling and Simulation)	Capabilities Increase

Quality Control Diagnostic System

- <u>Objective:</u> To design, purchase, integrate and install a Quality Control Diagnostic System involving a Near Infrared (NIR) Spectrometer and a Thermal Imaging Camera System to monitor online quality. The system monitors explosive and propellant compositions in real-time, providing almost instantaneous quality control feedback as product exits the TSE.

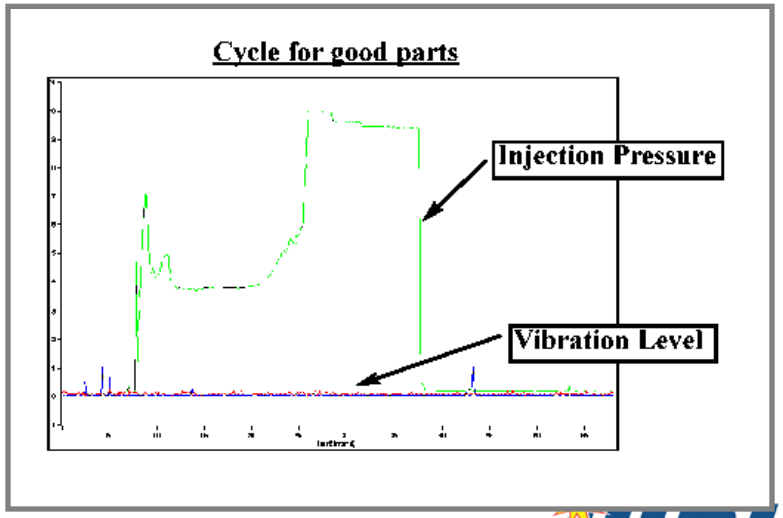




Thermal Image of Mk 66
2.75 " Grain

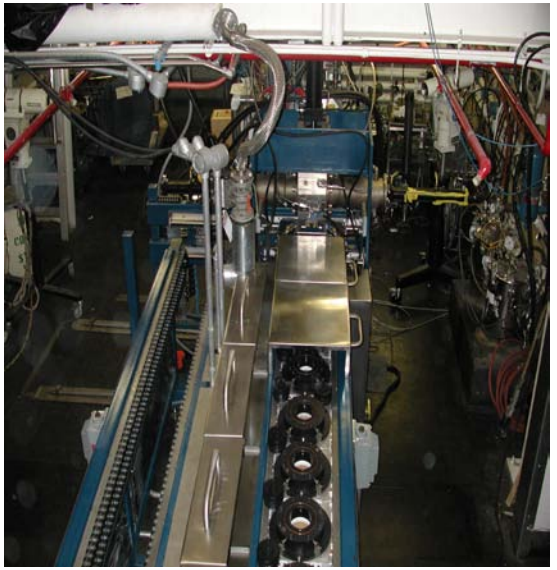
Acoustic Monitoring System

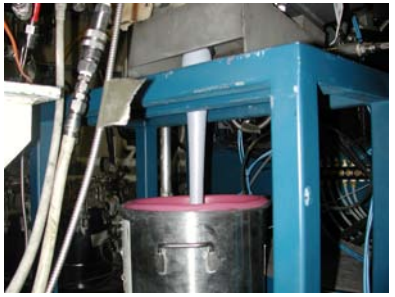
- Objective: To procure and demonstrate modern acoustic and vibration monitoring technology for characterizing equipment operation used in the development of advanced energetic materials (propellants, explosives, and pyrotechnics). The equipment can be used to alarm on abnormal signals thus increasing process safety.



Remote In-Line Vacuum Casting System

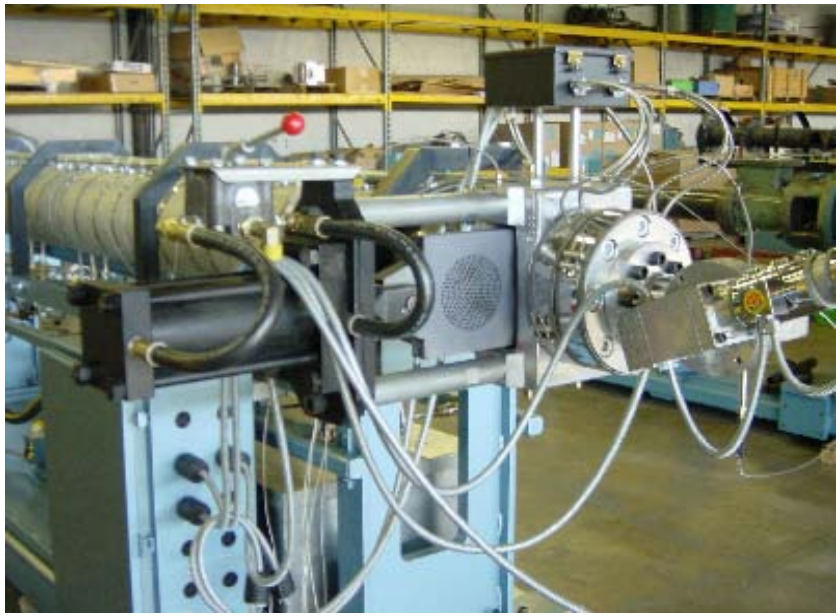
- Objective: To design, fabricate and install an online vacuum casting capability that will provide the flexibility to manufacture a variety of rocket motors and warheads in a continuous manner. This technology will improve safety by eliminating the attended casting operation. It will also increase productivity by reducing processing steps.





Remote In-Line Cutter for Small Diameter Energetics

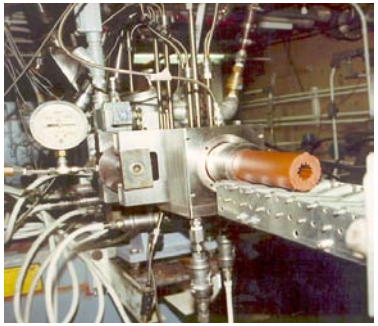
- Objective: To design, fabricate and install an in-line cutting system that will increase the continuous processing capabilities. This capability will provide flexibility to process and perform online cutting of a variety of extruded strand sizes. It will also increase safety by removing the need for operator attended cutting operations.



Small Diameter Cutting System

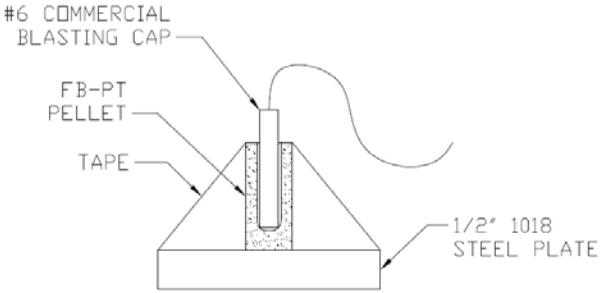
DOD Surplused Explosives

- Objective: To evaluate whether a commercially pressed explosive formulation can be transitioned to a TSE processed explosive due to the fact that the existing commercial processing capabilities can not meet the potential future requirements.



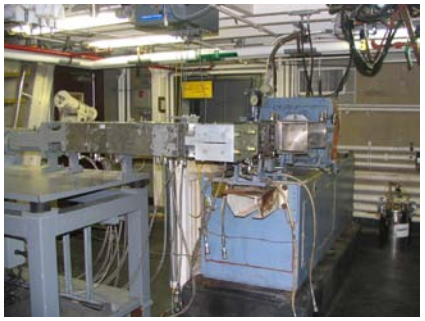
40mm Twin Screw Extruder

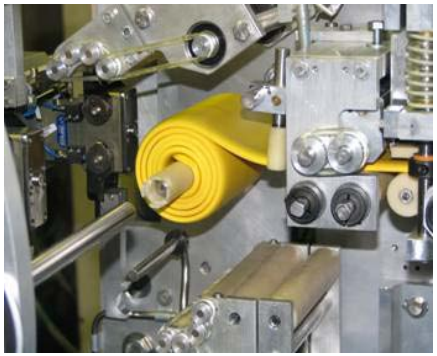
Tophat and Sleeve



Flexible Manufacturing of Nitrogen Gun Propellants

- <u>Objective:</u> To develop a manufacturing process to produce multiple configurations of advanced gun propellants at high volume and low cost by using high nitrogen ingredients that decrease barrel erosion.





- Detailed IHDIV presentation to follow.

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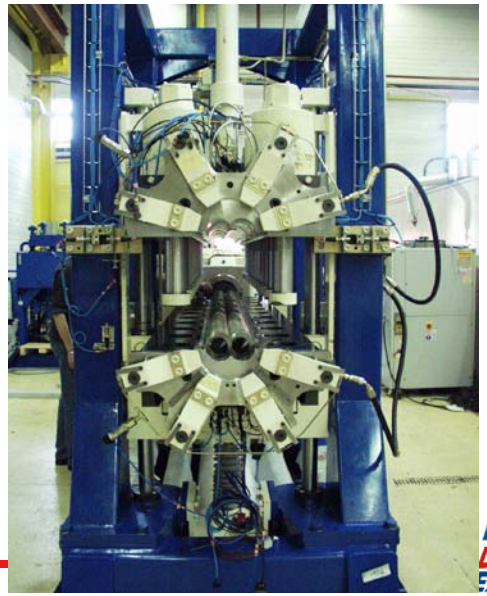
Continuous Processing Scale-Up Facility Start Up (88mm TSE)

- Objective: To commission and demonstrate the MK99 LOVA propellant manufacturing technology in the 88mm TSE Facility.

- Detailed IHDIV presentation to follow.



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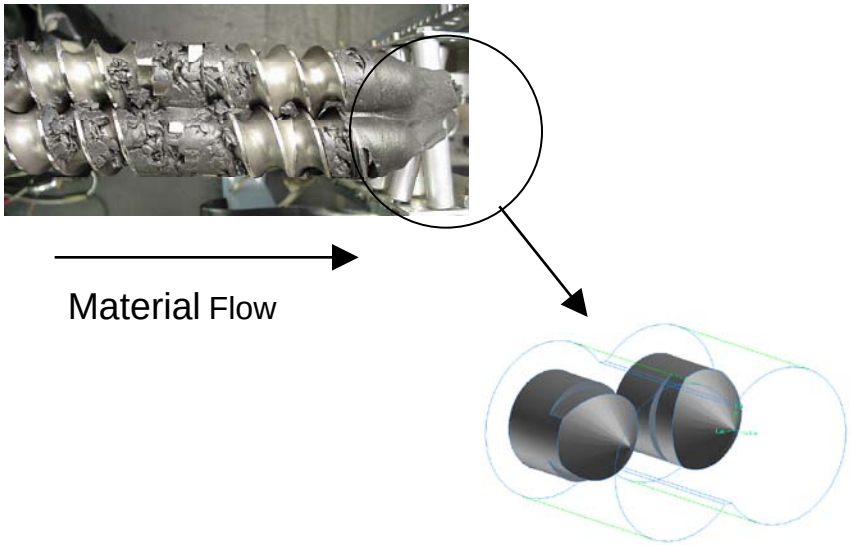
TSE Material Characterization

- Objective: To develop an in-house TSE Temperature Response Model to estimate the maximum temperature at the TSE screw tip area and evaluate models to characterize material thermal hazards using small-scale lab tests. This capability will reduce the design/development cycle time/costs for new TSE process and better define the thermal hazards.
- Request for TSE Safety Protocol Information
- Detailed IHDIV presentation to follow.



Geometry of TSE Screw-Tip Area

Summary

- Indian Head Division has a Full Spectrum of Continuous Processing Capabilities from Material Characterization Through Scale-Up Manufacturing
- Executing Current Projects and Increasing Technical Experience Base
- Building for the Future in the Continuous Processing Arena