EFFICIENT HYBRID ACTUATION USING SOLID-STATE ACTUATORS

Virginia Tech

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Grant Number NAG-1-2190
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Objective and Program Scope

- Objective
  - Develop energy efficient hybrid actuators consisting of piezoelectric materials and hydraulic energy storage elements.
- Program Scope
  - Concept Development / Verification
  - Piezohydraulic Modeling
  - Efficient Electronics Development
  - Benchtop Systems Development

Milestones

	1999				2000							
	S	O	N	D	J	F	M	A	M	J	J	A
Concept Design / Development				●								
Benchtop System Built					●							
Rev A Amplifier Delivered							●					
System Tests Completed										●		
Modeling / Correlation Completed											●	
Final Amplifier Delivered												●
Benchtop System Delivered												●

Work in Progress

- System Tests
- Piezohydraulic Modeling

Work to be Completed

- Final Amplifier Delivery
- Benchtop System Delivery

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Performers

Contractor	Objective	Status
Virginia Tech	Concept Development	✓
	Concept Verification	✓
	Piezohydraulic Modeling	In Progress
	Benchtop Testing	✓
	Systems Integration / Delivery	
DSM	Charge Recirculating Design	✓
	Rev A Built / Delivered	✓
	Final Amplifier Built / Delivered	

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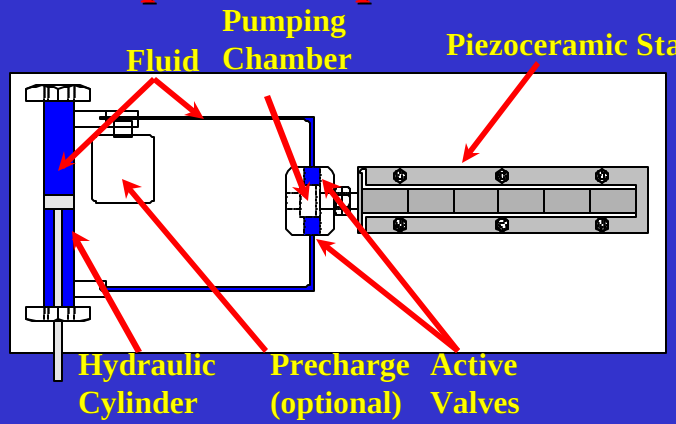
Major Accomplishments

Concept Development



Efficient Electronics

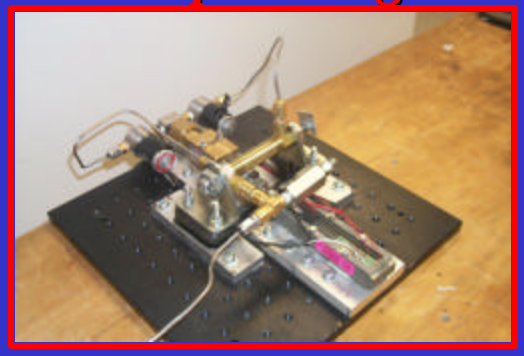
3-Channels:
1x150 Volts,
2x400 Volts.

Max Current of 1.8 amps.

Prototype is 13 x 9 inch

Produces 270 Watts

Benchtop Testing



50 N Force

230 um/sec

limitation:

valve response

compliance

Piezohydraulic Modeling

Completed

- Linear Hydraulic / Piezoelectric Elements
- Arbitrary Geometries
- Matlab-based code for control design and analysis

Work to be Completed

- Model correlation with experiment
- Geometry / Fluid / Control optimization

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Program Conclusion / Transition

Current Technical Challenges

Increasing valve response

Reducing parasitic compliance

will lead to

Increased bandwidth

Increased force

Year 1 Deliverables

Benchtop demonstration of piezohydraulic concept

Charge recirculating amplifier

Performance verification / quantification

Transition to other programs

Air Vehicle Control Surfaces

Active Flow Control for Gas Turbine Engines

Human performance enhancement

Target Application

Smart Fin Development (DC Military Aircraft)

Specifications

Bandwidth	50 Hz
Force	1000 N
Stroke	1.74 mm

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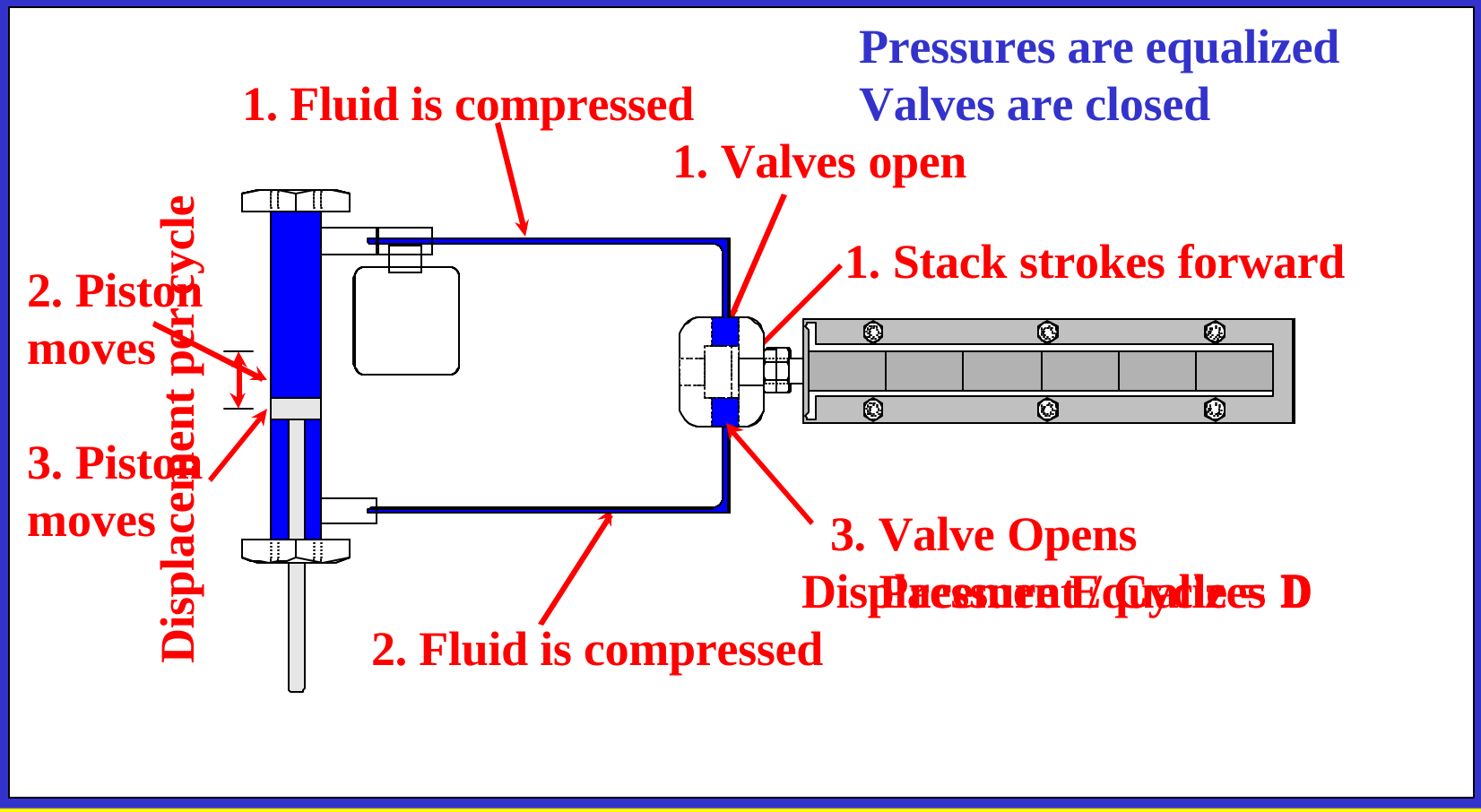
Actuator Operation



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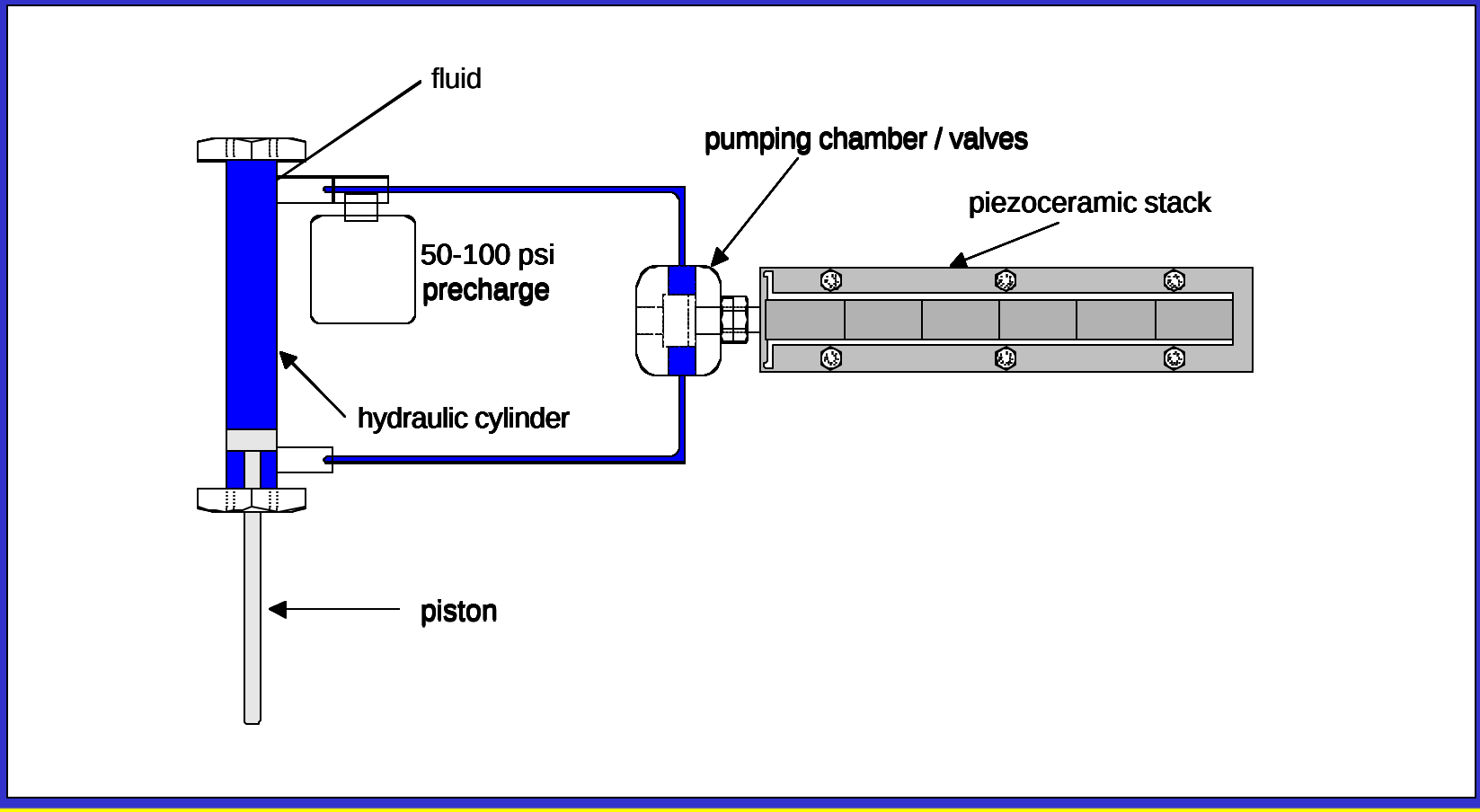
Phase I Concept



Phase I Concept

- Advantages
  - No need for accumulators - compact
  - Motion is software controlled
  - Highly scaleable
- Challenges
  - Valve timing / phasing (hardware and software)
  - System design incorporating fluid dynamics

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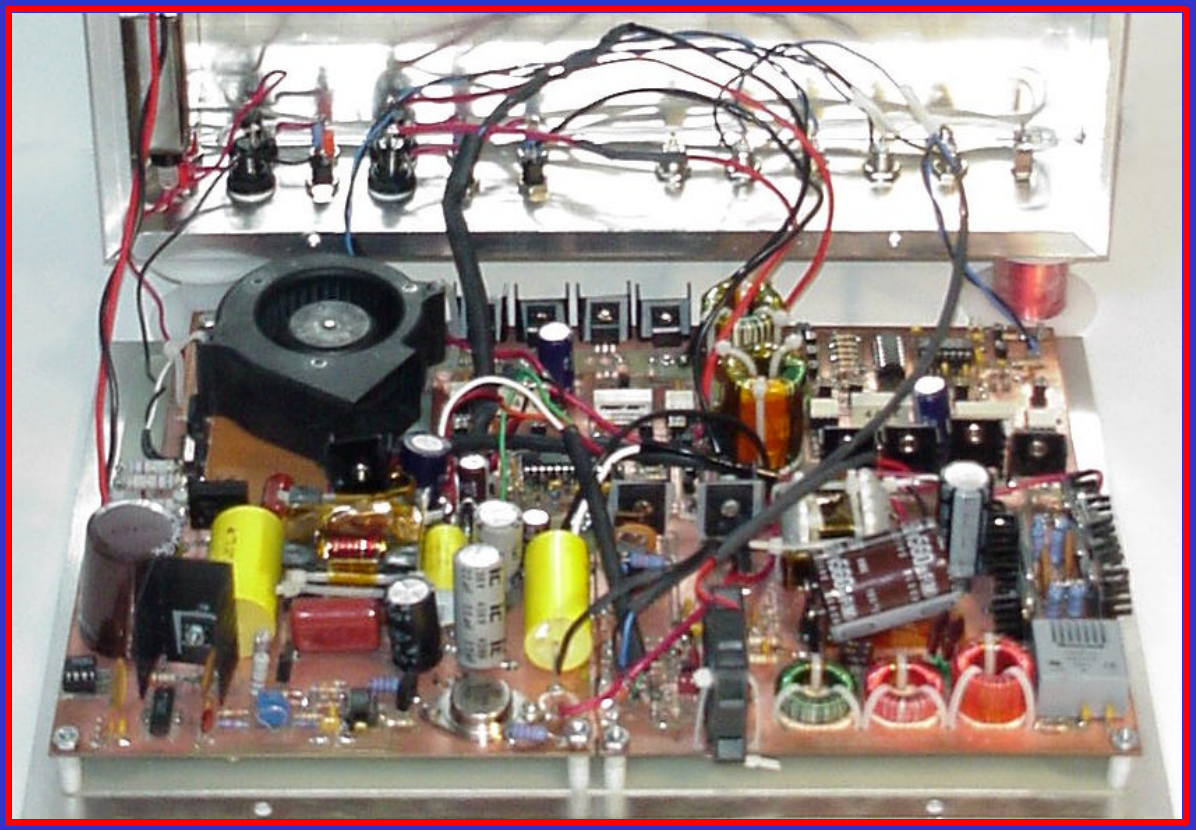
Second-Generation Charge Recirculating PZT Driver

Targeted for 3-Channels:
1x150 Volts,
2x400 Volts.

Max Current of 1.8 amps.

Prototype is 13 x 9 inch

Produces 270 Watts



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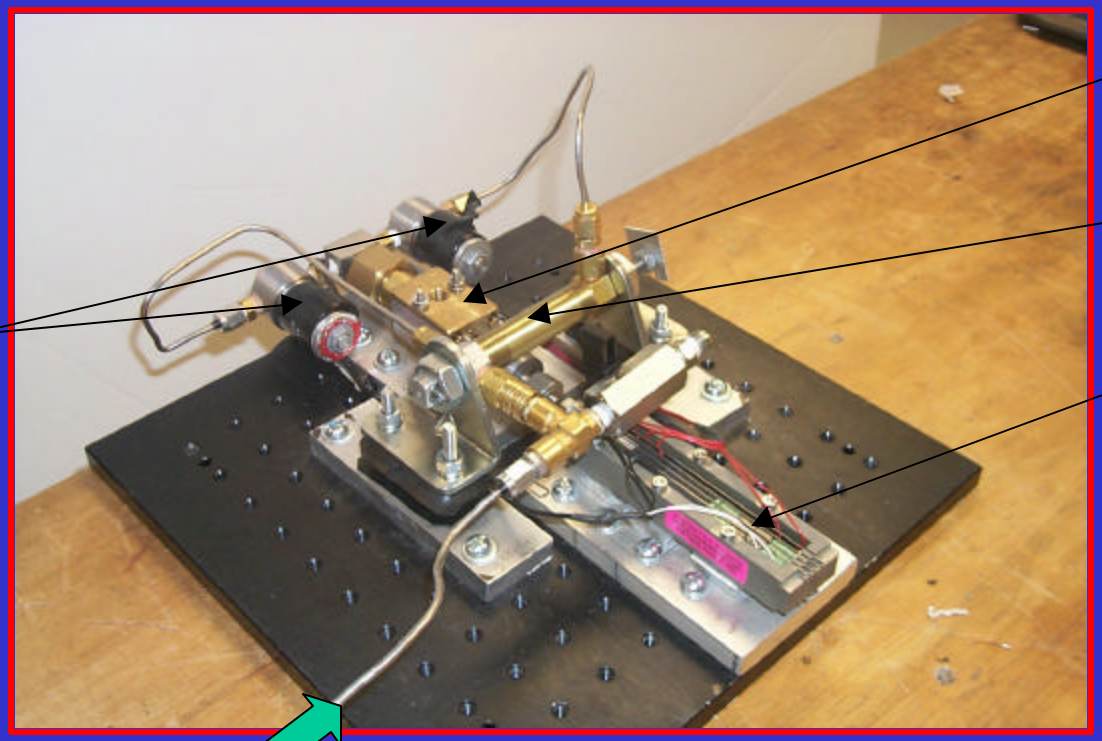
Benchtop Testing



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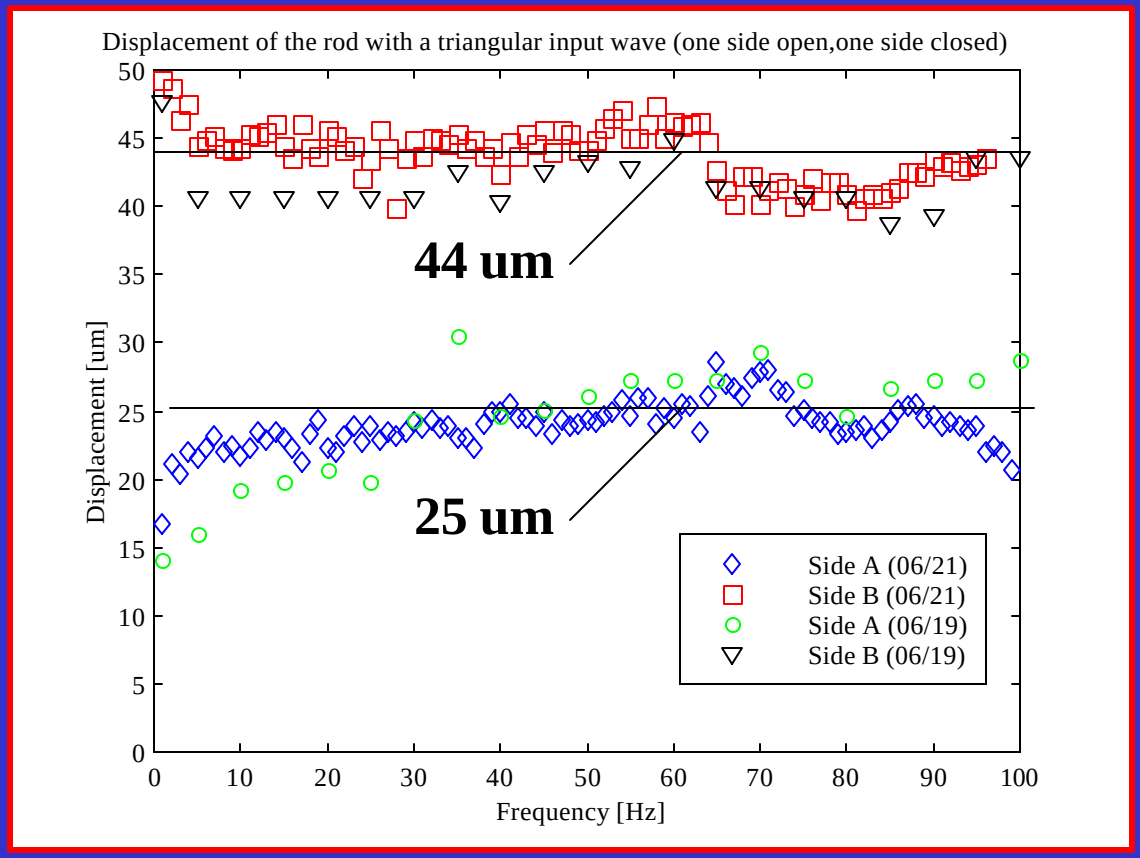
Dynamic Response



Displacement mismatch indicates asymmetric stiffness

Dynamic response is approximately flat to 100 Hz

Signal distortion indicates that bandwidth is on the order of 150 Hz.

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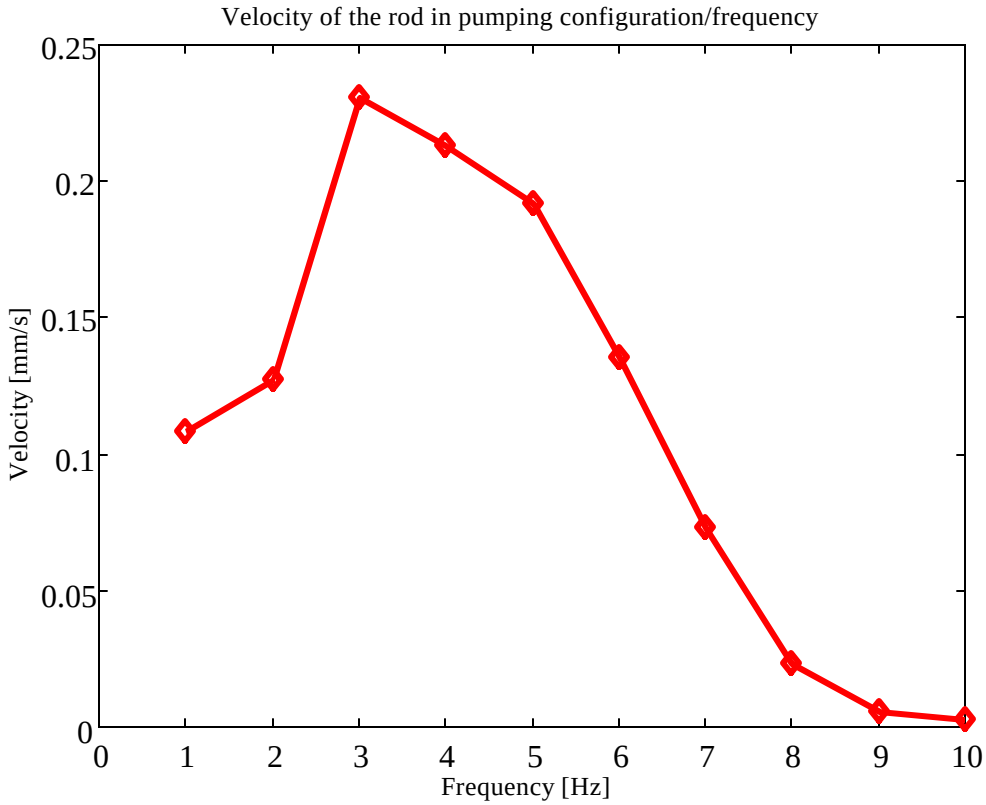
Piston Velocity



Piston velocity is limited to 230 um/sec by 3 Hz valve response

With faster valves:

6.9 mm/s at 100 Hz

11.5 mm/s at 150 Hz

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