Vehicular Hydrogen Transport System via Twin-Screw Extruder

HyTrans Engineering

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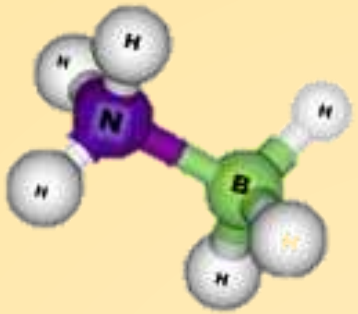
Introduction

- DOE Seeking Fossil Fuel Alternative for Vehicles
  - Scarcity of Fossil Fuels
    - Price of Gas May Become Greater than $6.00/gallon*
  - Predicted Depletion Dates**
    - Oil and Gas: 2042
    - Coal: 2112
  - Environment Concerns
    - Greenhouse Gases

*www.californiagasprices.com
**www.sciencedirect.com/science/article/pii/S0301421508004126

Introduction

- Possible Solutions
  - Electric Vehicles
    - Poor Range
    - Fossil Fuels Supply 68% of US Electricity**
  - Hydrogen-Powered Vehicles
    - Hydrogen is a Clean Fuel Carrier
    - Liquid & Gas Forms
      - Not Feasible
    - Solid Form
      - Ammonia Borane

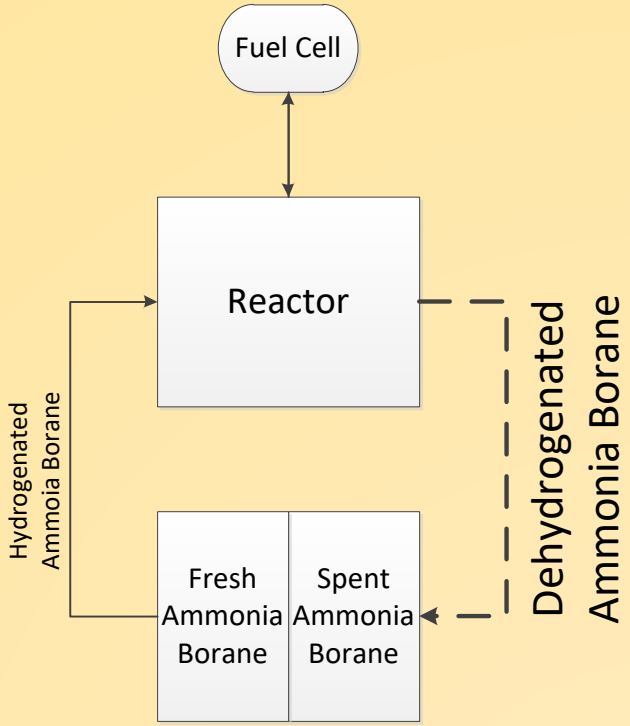


*Ammonia Borane

*www.americanelements.com/hydrogen-storage
**www.eia.gov/energyexplained/index.cfm?page=electricity_in_the_united_states

Introduction

- Hydrogen Transfer System for Vehicles
  - Ammonia Borane to Reactor
    - Hydrogen to Fuel Cell
  - Dehydrogenated Ammonia Borane
    - Reactor to Storage
- Previous Systems Unsuccessful
  - Focus of this Project



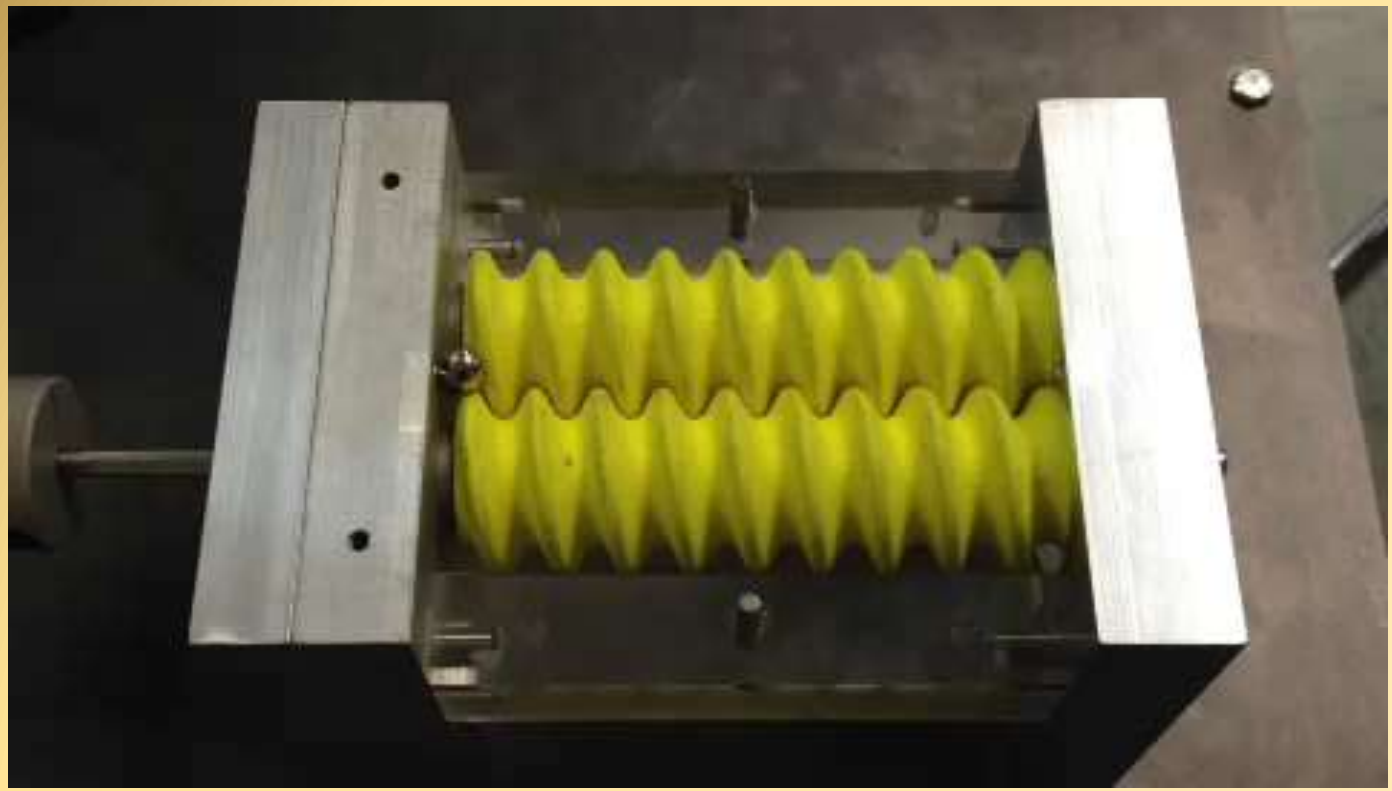
Transportation Ideas

- Auger
  - Clogs
  - HSECOE has Tried Without Success
- Twin Screw Extruder
  - Self Cleaning
  - Positive Pumping Action

*Auger Conveyor

*www.innovativeengineersindia.com/conveyor-system.html

Twin Screw Extruder



Design Process

- Design Specifications
- Surrogate Materials
- Screw Design Approach
- Compliance Testing
- Future Design Improvements
- Cost

Design Specifications

- $1/10^{th}$ Scale
  - $6.5 \frac{in^3}{min}$ Volumetric Flow Rate
- $1,000 Budget
- Surrogate for Ammonia Borane

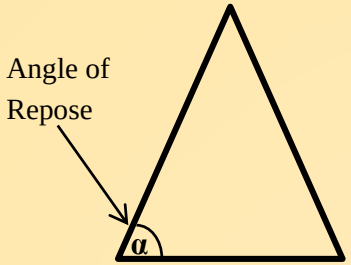
Surrogate Materials

- Comparison Properties

	Bulk Density (kg/L)	Particle Size (mm)	Angle of Repose (°)
Ammonia Borane	0.74	0.1-2	42
Low Density Polyethylene (LDPE)	0.92	0.1-1	42

*Spent Ammonia Borane

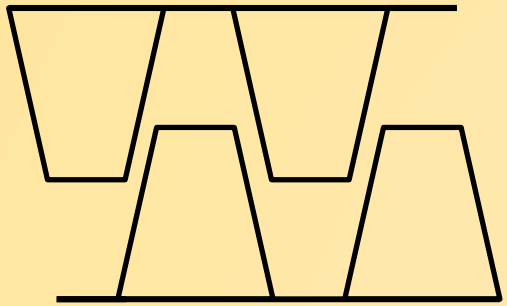
LDPE



Source: *Long Li & Yuan Zheng

Screw Design Approach

- Intermeshing
  - Screws Engage One Another Fully
- Conjugated
  - Threads Perfectly Fit Into One Another



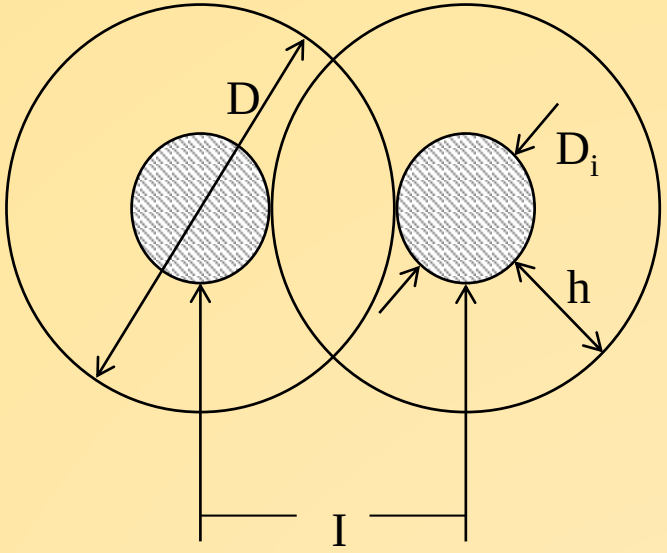
Screw Design Approach

$$I < D \ll 2I$$

$$0 \ll D_i < I$$

$$D + D_i = 2I = Constant$$

$$h = D - I$$



I [in]	1.25
D [in]	1.5
D_i [in]	1
h [in]	0.25
pitch [in/thread]	0.25 & 0.50

*Twin-Screw Extruders: Dr. F. Martelli

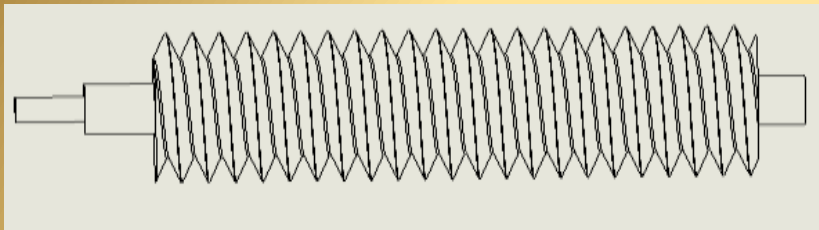
Screw Design Approach

- Mass Flow Rate: $\dot{m}_{AB} = \frac{9 \cdot P}{LHV \cdot \eta}$
- Volumetric Flow Rate: $\dot{Q}_{AB} = \frac{\dot{m}_{AB}}{\rho_{AB}}$
- 1/10th Scale: $\dot{Q}_{SCALE} = \frac{\dot{Q}_{AB}}{10} = 6.5 \frac{in^3}{min}$

Screw Design Approach

- Target Flow Rate: $\dot{Q} = 2 \cdot V \cdot n$
- Thread Volume Per Revolution: $V = A \cdot S$
- Cross Sectional Area of Thread : $A = \frac{\dot{Q}}{2 \cdot S \cdot n}$

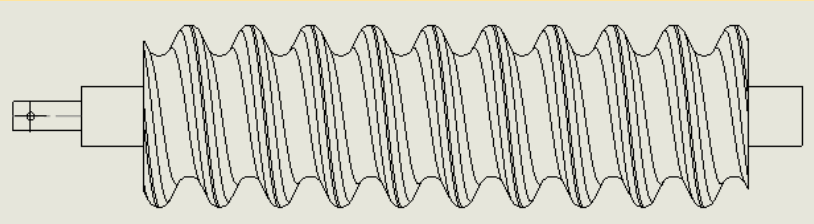
Screw Design



Triangular Threads:

A = 0.03 in²
V = 2.5 in³

Predicted Screw Velocity to Reach Target Flow Rate = 47rpm*



Rounded Threads:

A = 0.07 in²
V = 2.5 in³

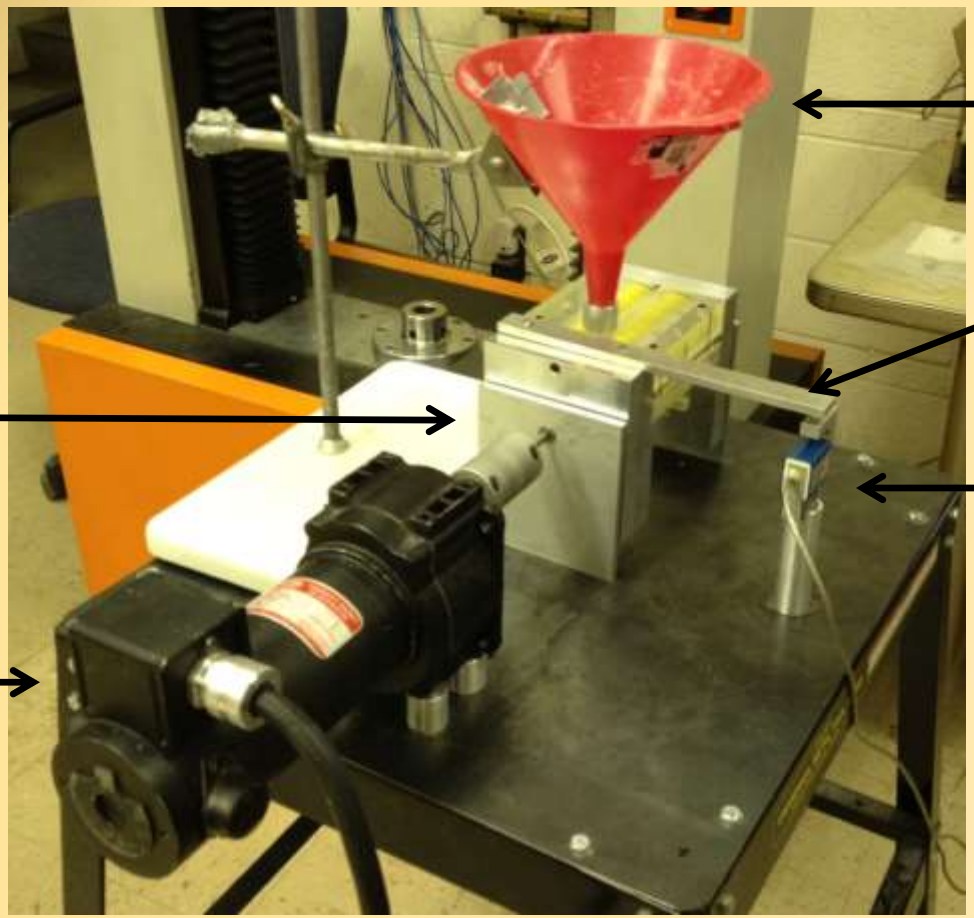
Predicted Screw Velocity to Reach Target Flow Rate = 20rpm*

* With 100% Fill

Compliance Testing

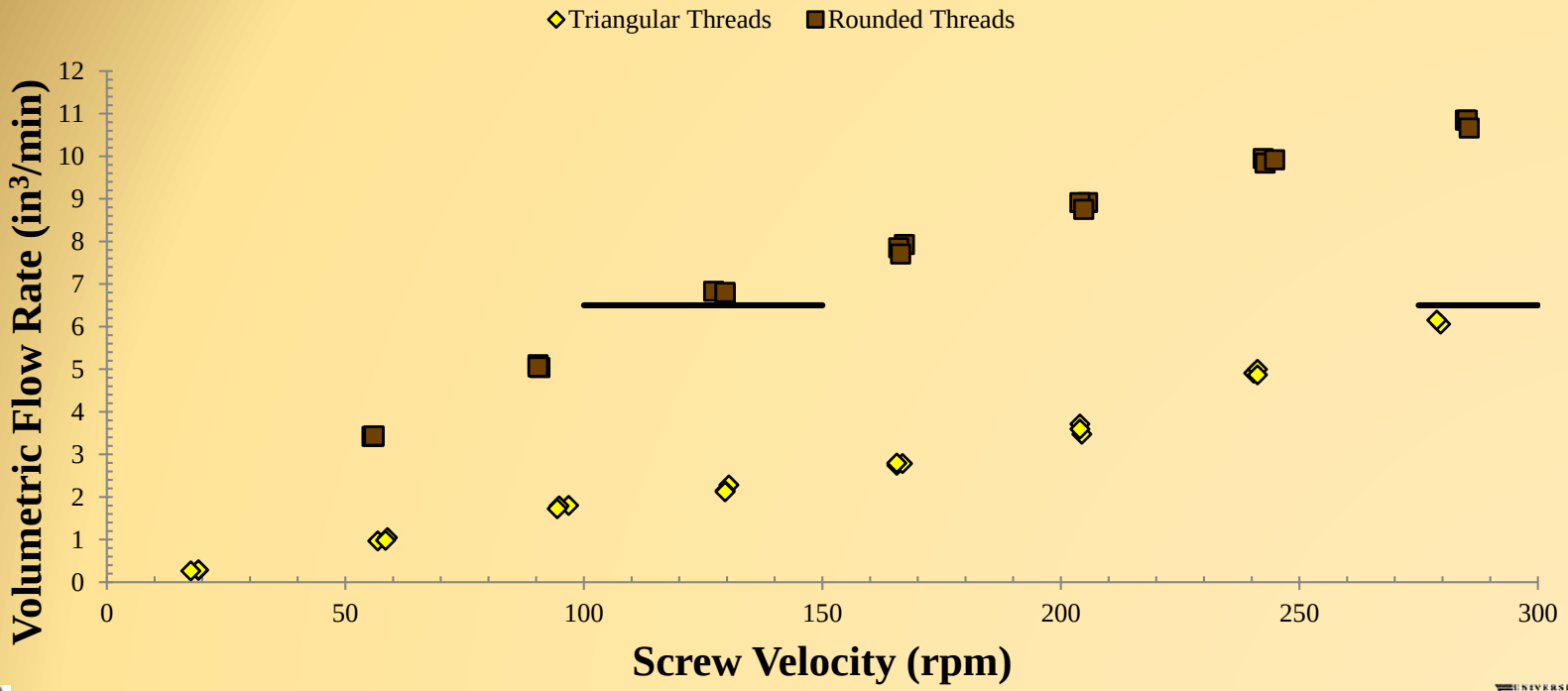
- Set Up
  - Variable DC Motor
  - Motor Cradle
  - Lever Arm on a Force Transducer
  - Mass Scale
- Measurements
  - Force to Dynamic Torque
  - Mass Flow Rate at Variable Speeds

Compliance Testing

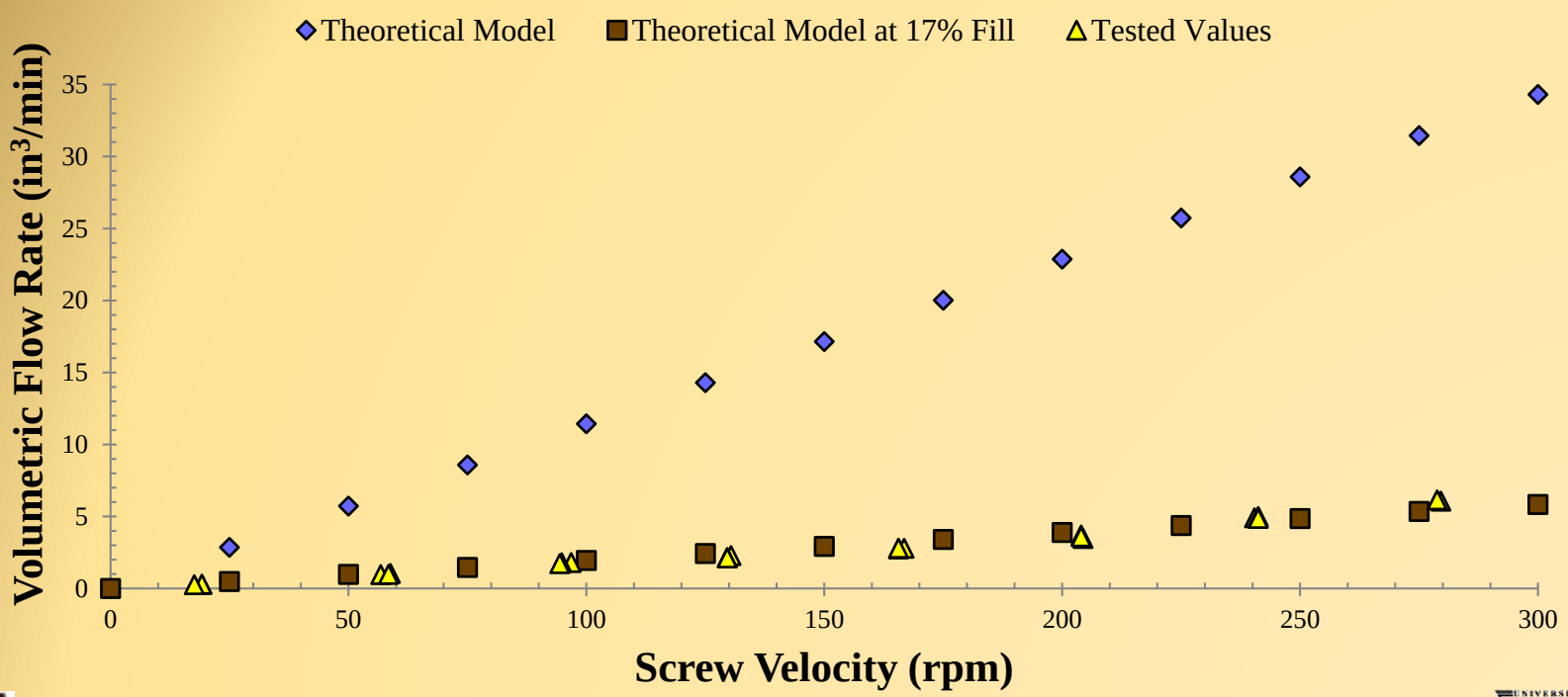


Compliance Testing

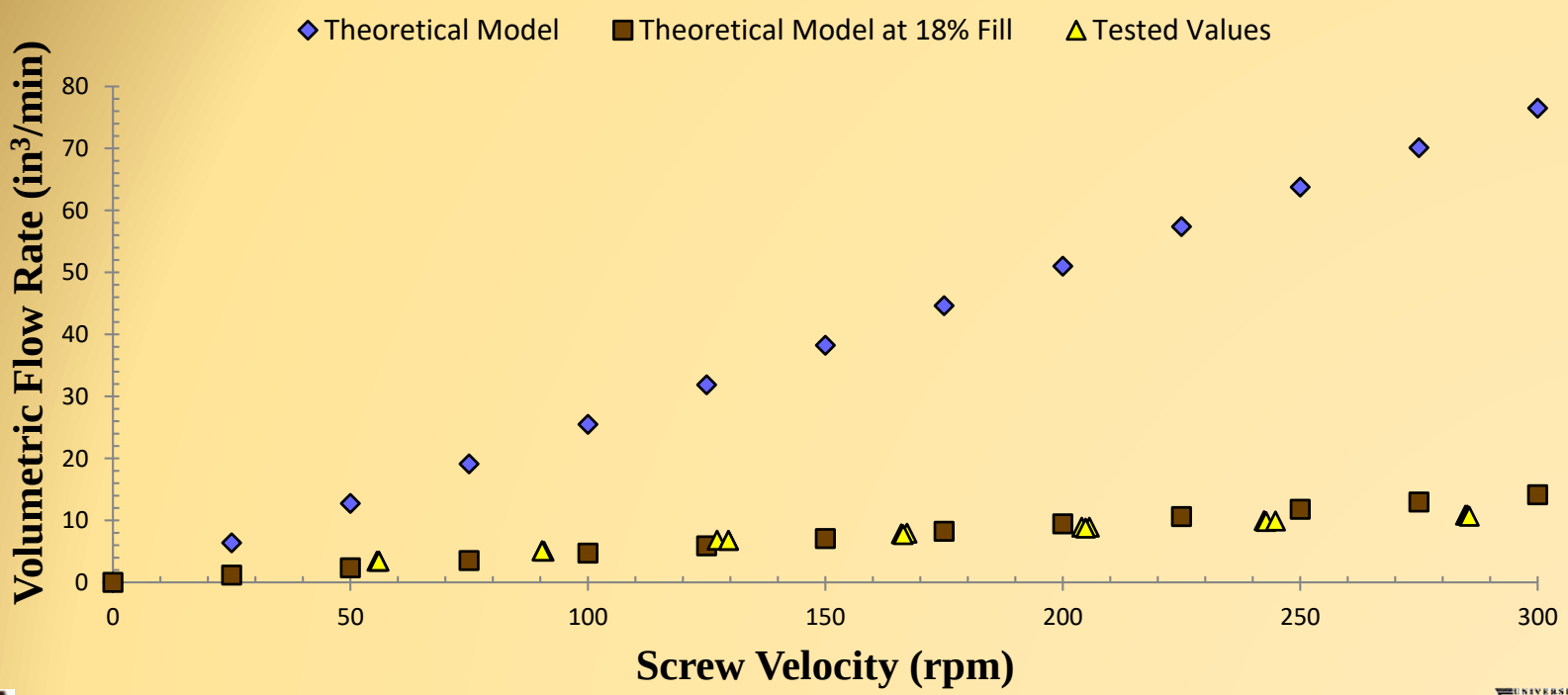
Optimizing Screw Geometry



Compliance Testing

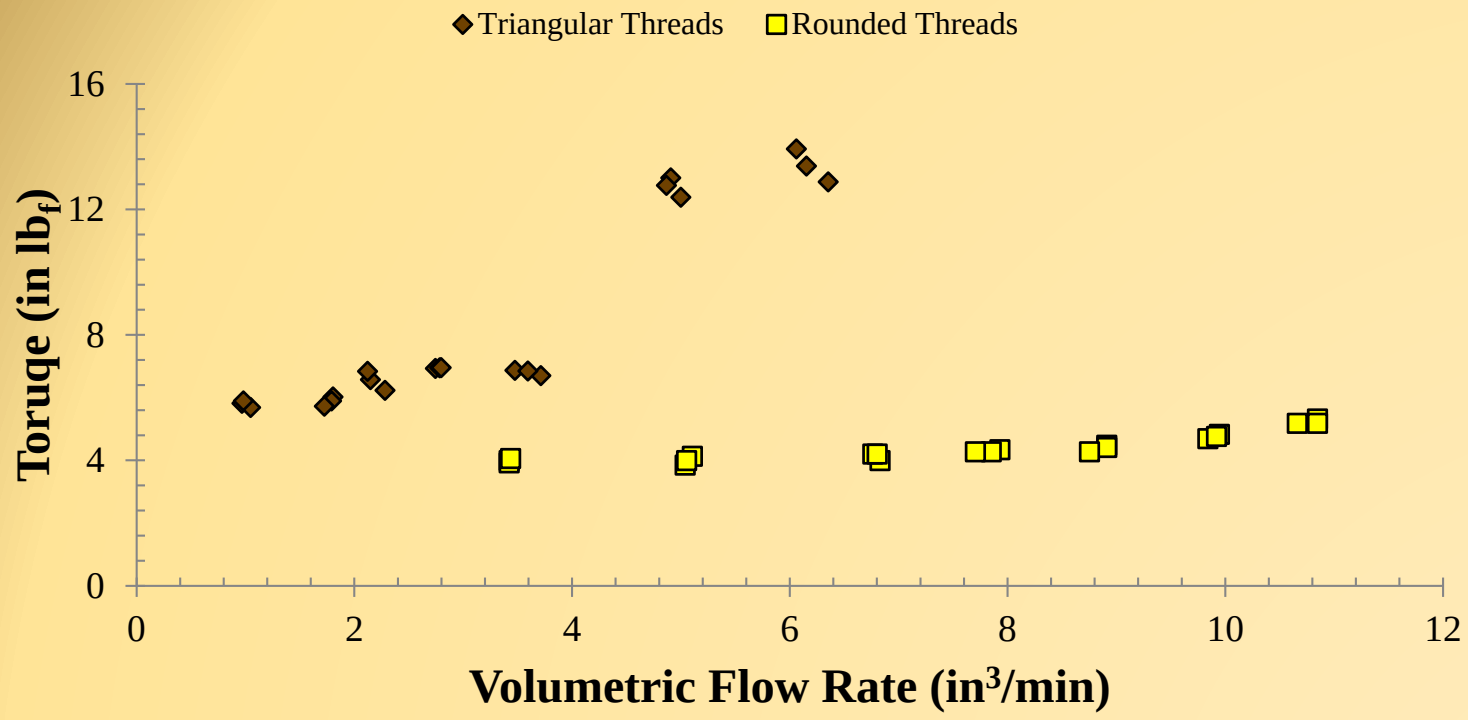


Compliance Testing



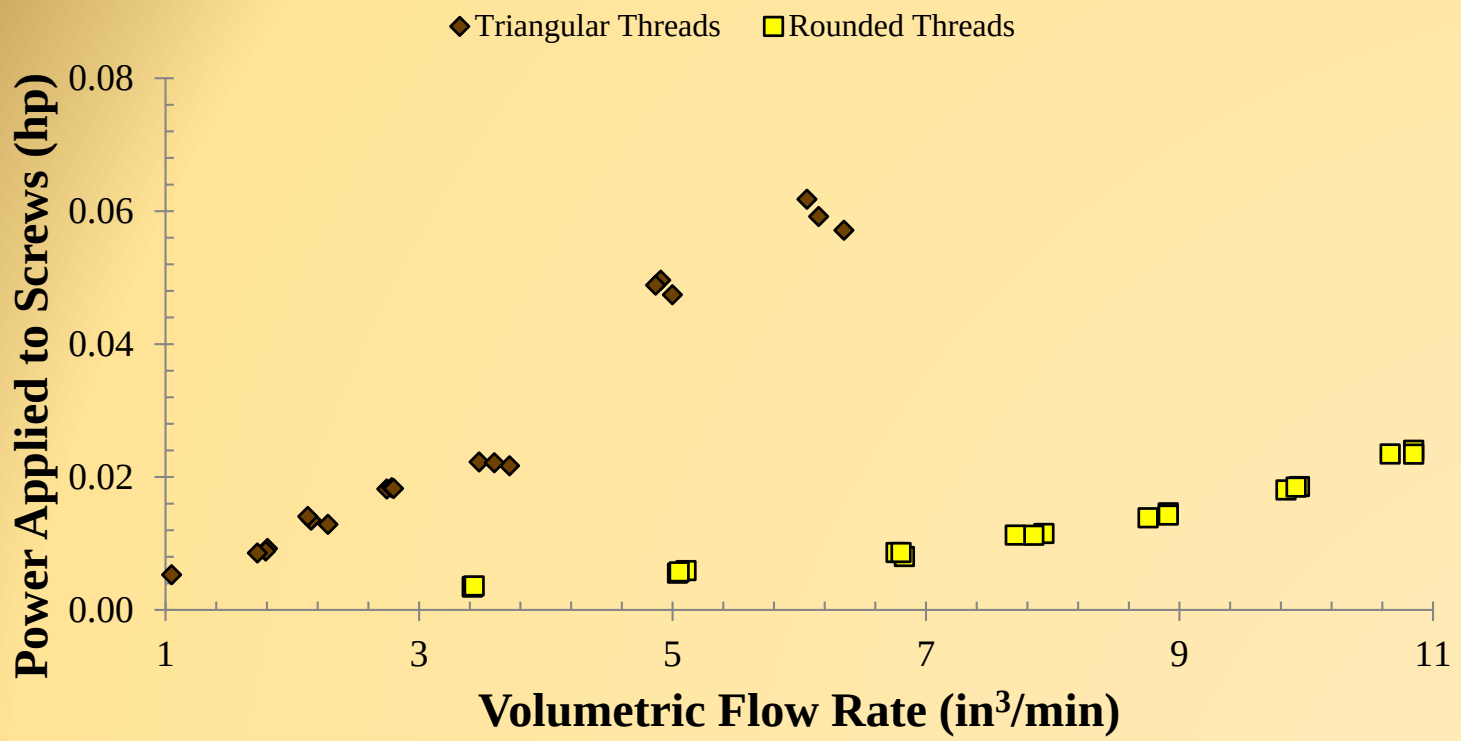
Compliance Testing

Torque - Flow Rate Relationship



Compliance Testing

Power - Flow Rate Relationship



Future Design Improvements

- Screw Material
  - Less Friction
    - Reduced Power
- Screw Geometry
  - Faster Flow Rates
  - Reduced Power Requirements
- Larger Material Inlet Area in Casing
- Full Scale Possibilities

Project Cost

Expense	Quantity (Hrs)	Total Cost
HyTrans Engineering	877	$32,100
Machine Shop	59	$3,500
Materials		$300
	Grand Total:	**$35,900**

Questions?