VRLA Battery Separator: Polymer Production

Group 10

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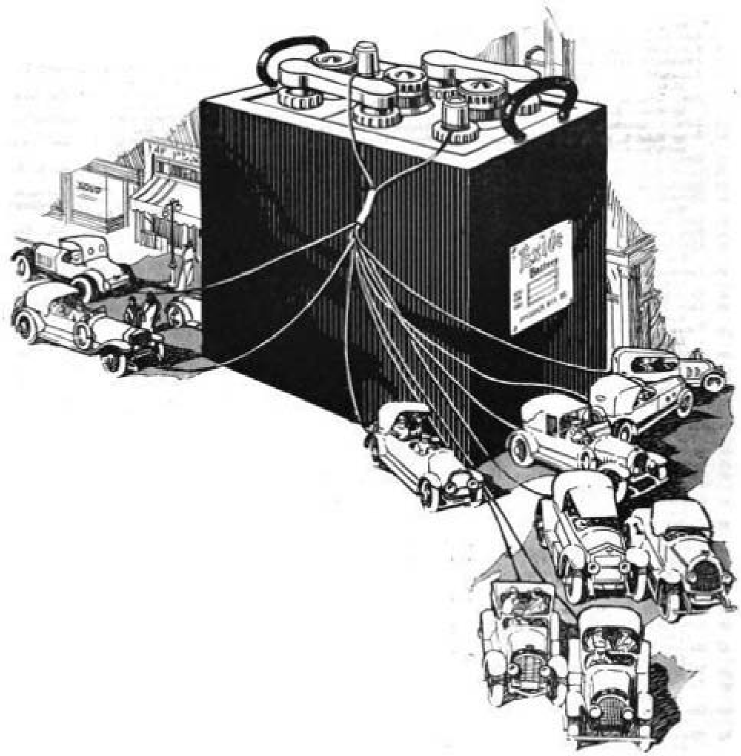


Project Overview

- **Current Technology:** AGM separator
- **Project Objective:** Replace AGM with polymer separator
  - Forecasted 2012 Production Volume: 1.75 MM m^2 separator mat
  - Chosen Polymer System:
    0.6 wt % maleated polypropylene (PP-MAH)
- **Two Processes Considered Simultaneously**
  - PP Plant (20,000 kg/hr)
  - MAH Grafting of PP (34 kg/hr)
- **Recommendation:**
  Buy PP-MAH pellets from an outside supplier

Spheripol Polypropylene Production

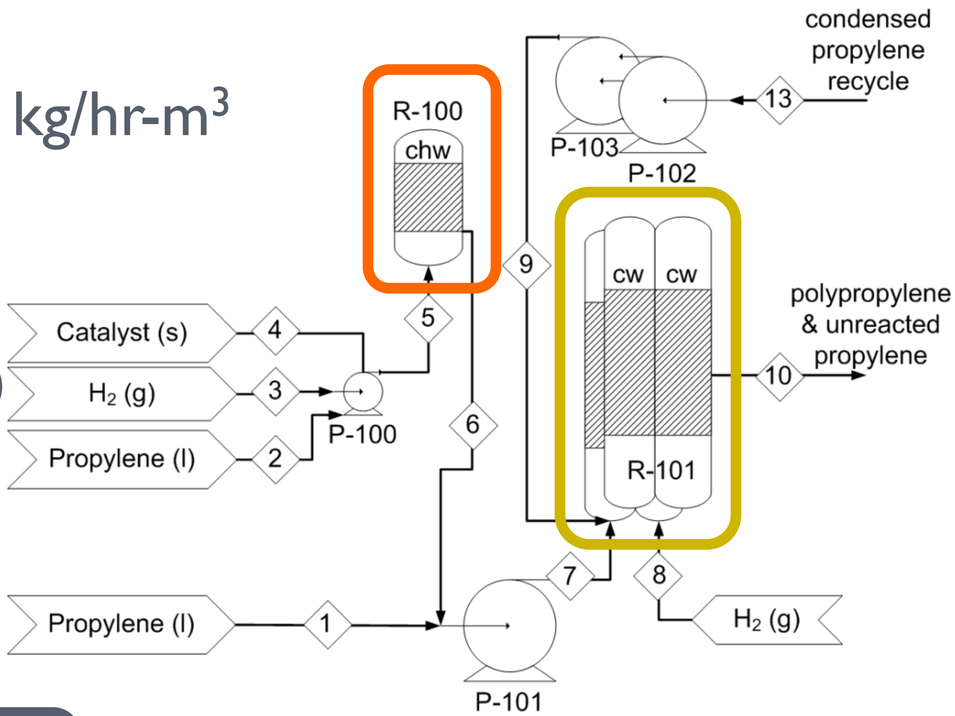
- Specific PP production: 400 kg/hr-m^3
- Prepolymerization (R-100)
  - 20 °C, 4 MPa, 0.5 m^3
- Bulk polymerization (R-101)
  - 70 °C, 4 MPa, 49.5 m^3
- L/D_i = 160
- Recycle ratio = 30
  - Re = 6.2x10^6
- Low-alloy steel

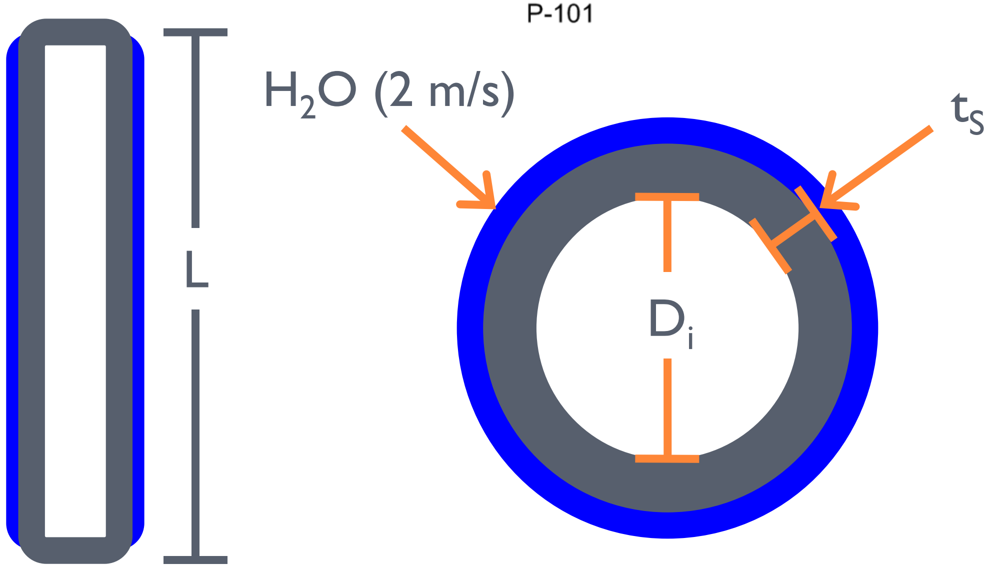
$$V = 0.25\pi D_i^2 L$$

$$Q = \dot{m}\Delta H_{rxn} = UA\Delta T_m$$

$$A = 0.80\pi L\left(D_i + 2t_S\right)$$

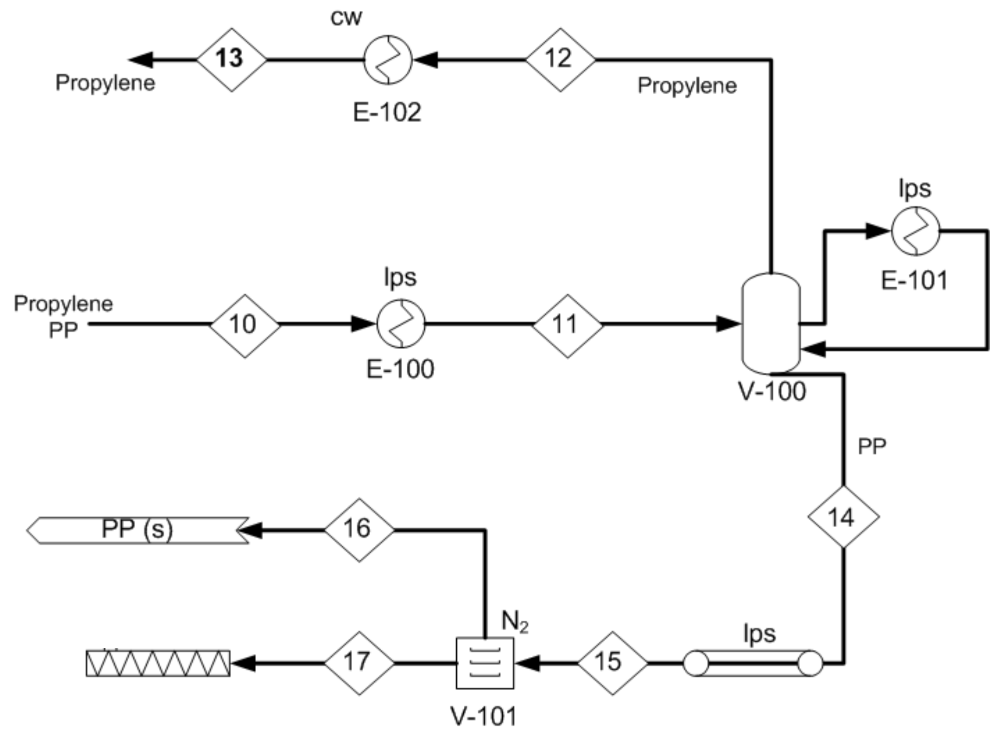
$$U = 1.745\ kJ / m^2 \cdot K \cdot s$$





Polypropylene Purification

- Heater (E-100)
- Flash (V-100)
- Adjunct Heater (E-101)
- Cooler (E-102)
- Pneumatic Conveyor (LPS)
- Direct-Heat Rotary Dryer (E-7)



For 3<L/D<5:

$$(u_V)_{\max} = K_V \sqrt{\frac{\rho_l - \rho_V}{\rho_V}}$$

$$A_{cross,\min} = \frac{Q_V}{(u_V)_{\max}}$$

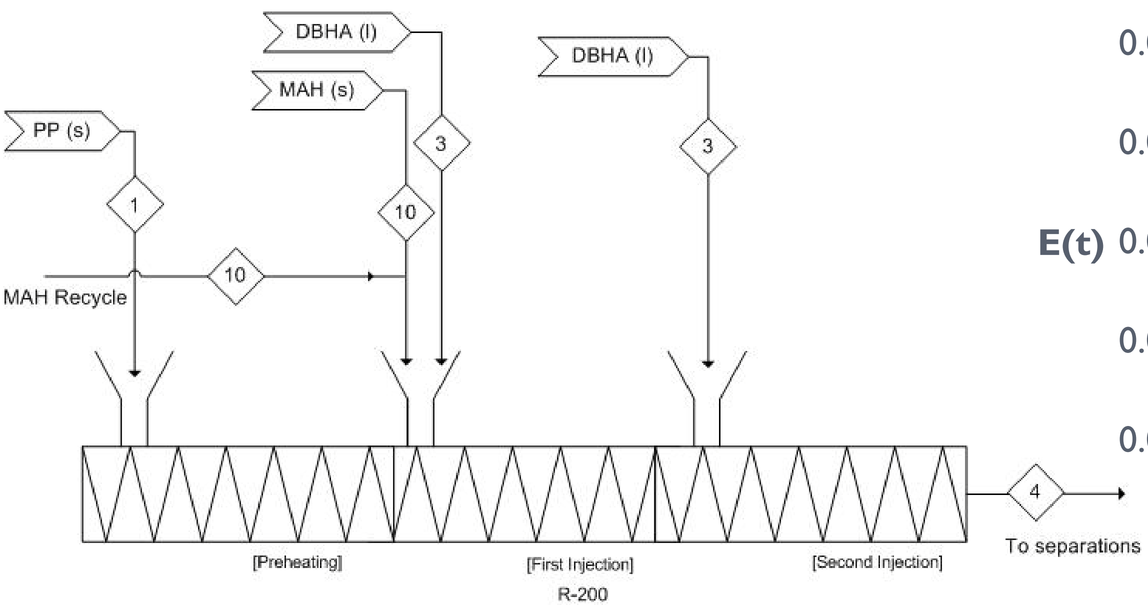
Watkins, R.N., "Sizing Separators and Accumulators", Hydrocarbon Processing, November 1967, p. 253.
GPSA Engineering Data Book

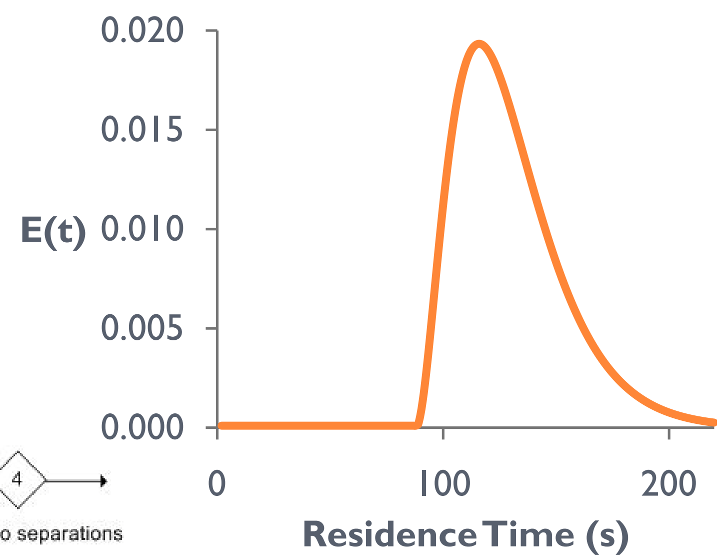
Maleation of Polypropylene

- Three Segments
  - Melting/Preheating
  - First DBHA injection (0.001 *M*)
  - Second DBHA injection (0.001 *M*)

$$\frac{-d[M]}{dt} = \frac{k_g}{1+f}\sqrt{\frac{2k_d(1+k_d t)e^{-k_d t}[I_0]}{k_t}}[M]$$

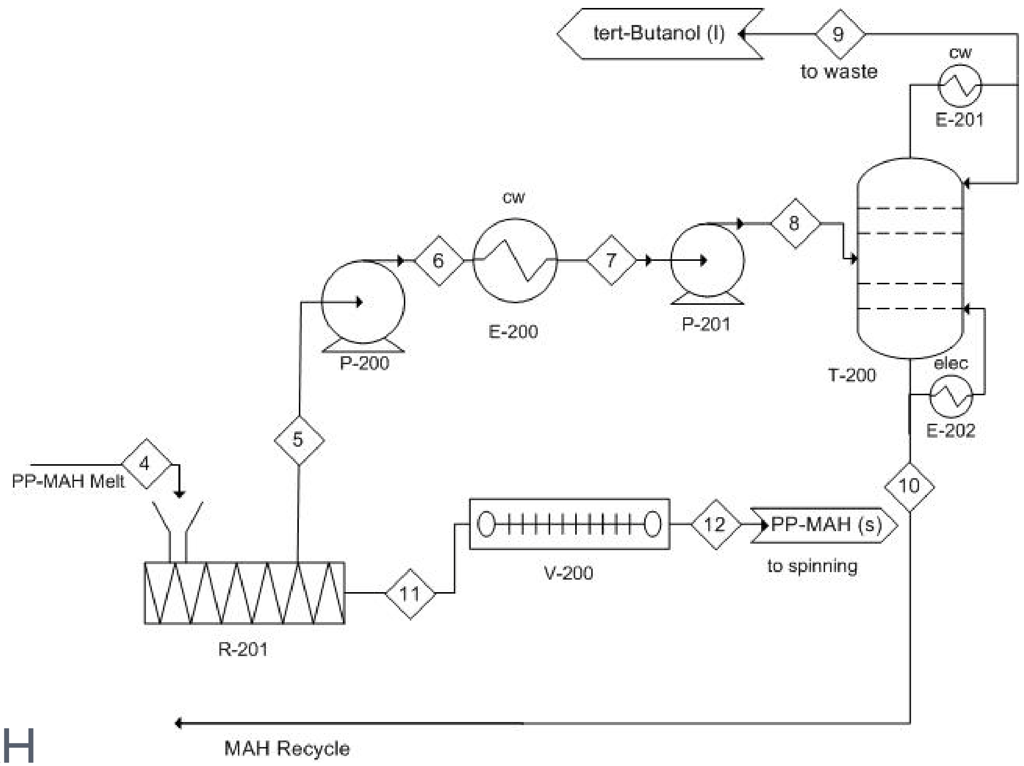
- Each segment 0.6 m in length
- L/D = 42
- Extruder operates at 180 °C
- Overall MAH conversion: 13 %
- 10 kW heating provided by electricity





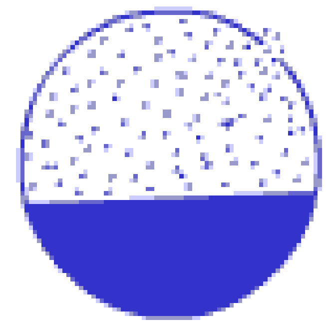
SEPARATIONS

- Devolatizer
  - Modeled products as *tert*-Butanol and MAH only
  - Operate at 190 °C
- Distillation Case
  - Vacuum pump (P-200)
  - Cooler (E-200) – condense vapor
  - Pump (P-201) – raise pressure to 101 kPa
  - Column (T-200) – separate *tert*-Butanol and MAH
  - MAH is recycled to extruder
- Alternative Separation Schemes
  - Flash separation
  - Strictly waste disposal

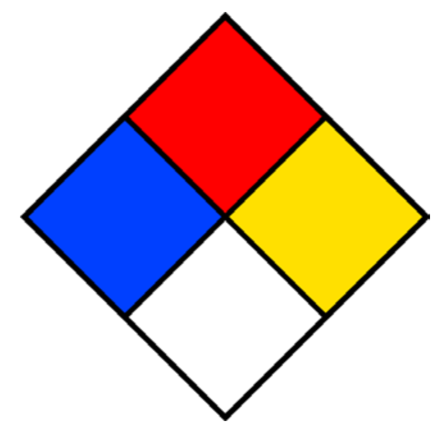


Safety & Environmental Considerations

- Process Hazards
  - Exothermic polymerization
  - High pressures (BLEVE & VCE)
  - High temperatures



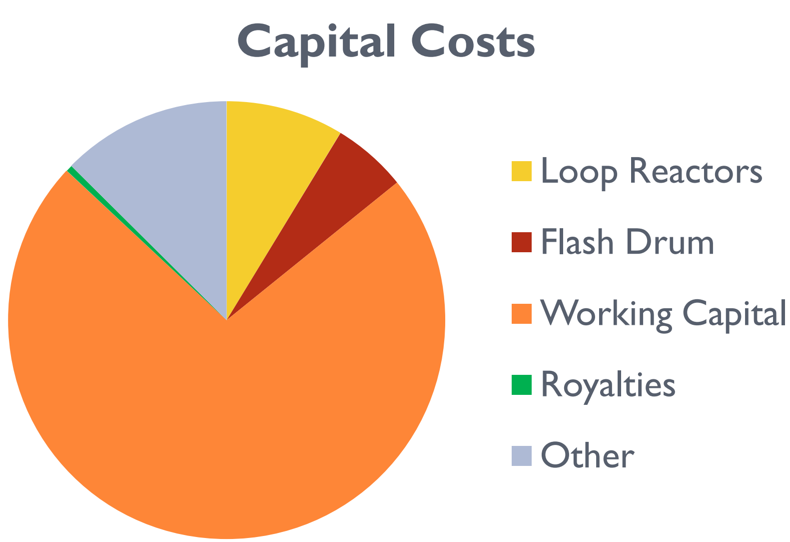
Material	Health	Flammability	Reactivity
Propylene	1	4	1
Hydrogen	0	4	0
MAH	3	1	1
DBHA	1	2	2
tert-Butanol	1	3	0

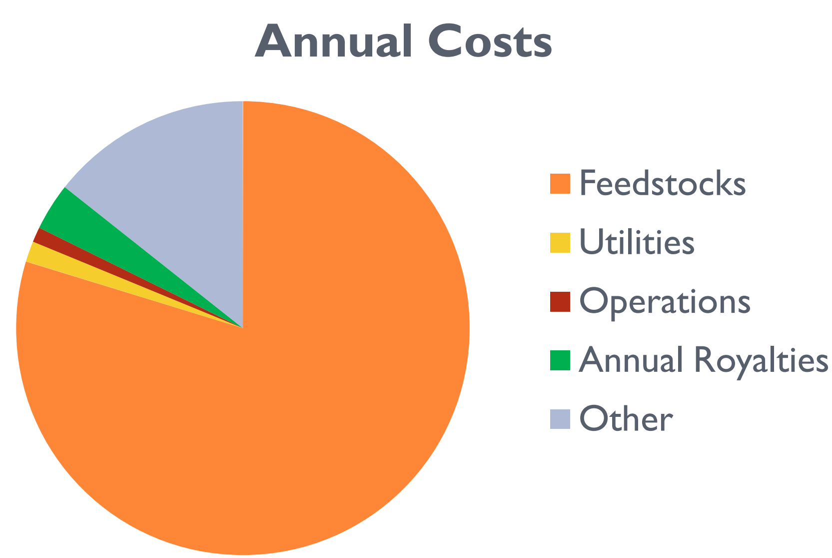


Economic Analysis of Spheripol Process

- **PP Production**
  - C_{TCI}: $41 MM
    - Working Capital: 73%
  - Annual Sales: $276 MM

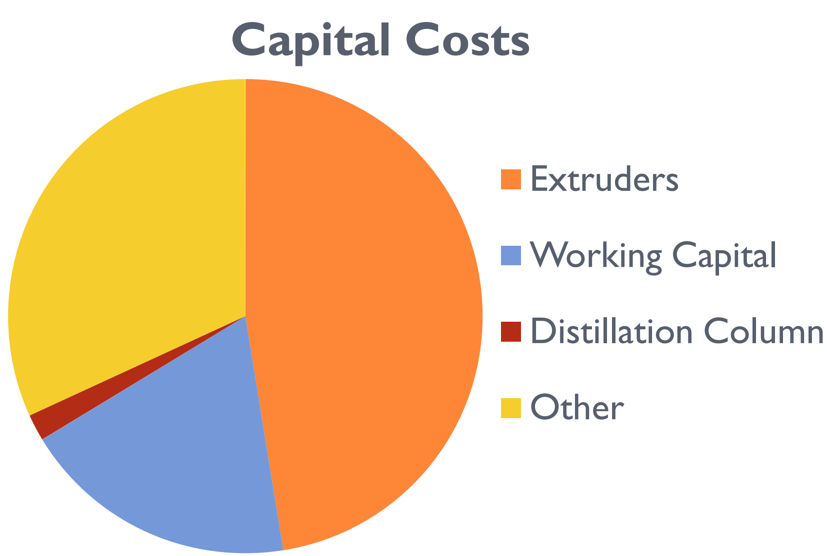
- Annual Production Cost: $245 MM
  - 3.5 operators per shift
  - Feedstocks: 83%
- Annual Royalties: $8.3 MM
- IRR: 93%
- Payback Period: ~0.5 years

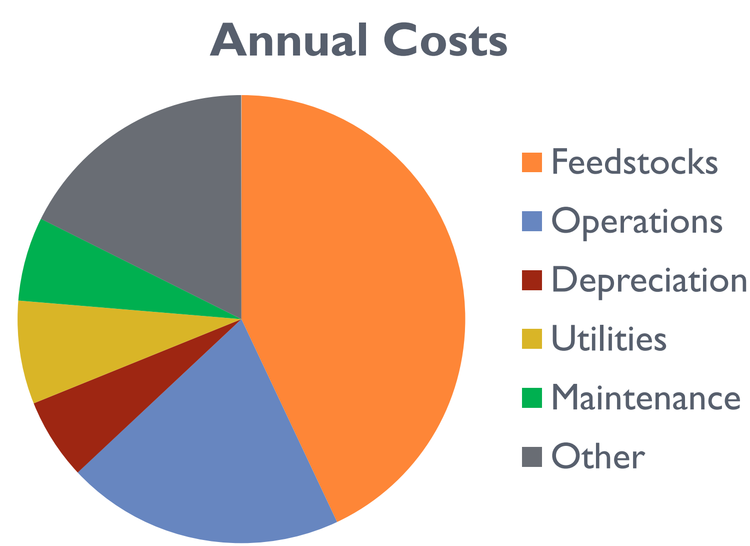




Economic Analysis of Grafting

- **Grafting**
  - C_{TCI}: $1.01 MM
    - No storage
    - Extruders: 48%
  - Annual Sales: $1.40 MM
- Annual Production Cost: $1.27 MM
  - 0.5 operators per shift
  - Operations: 20%
- IRR: 30%
- Payback Period: ~6 years



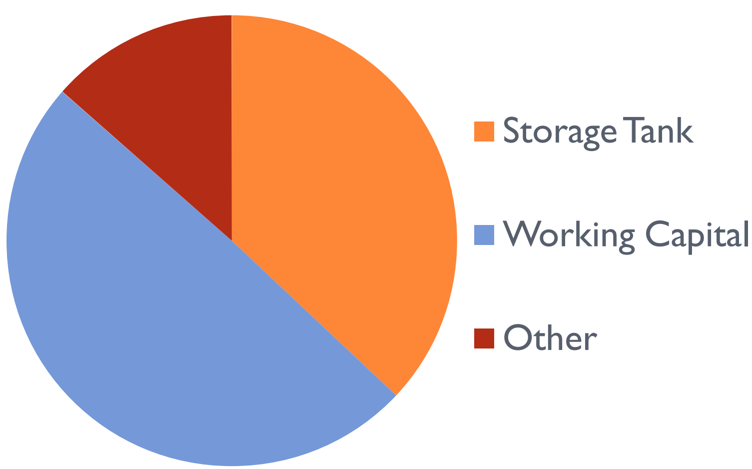


Economic Analysis of Grafting

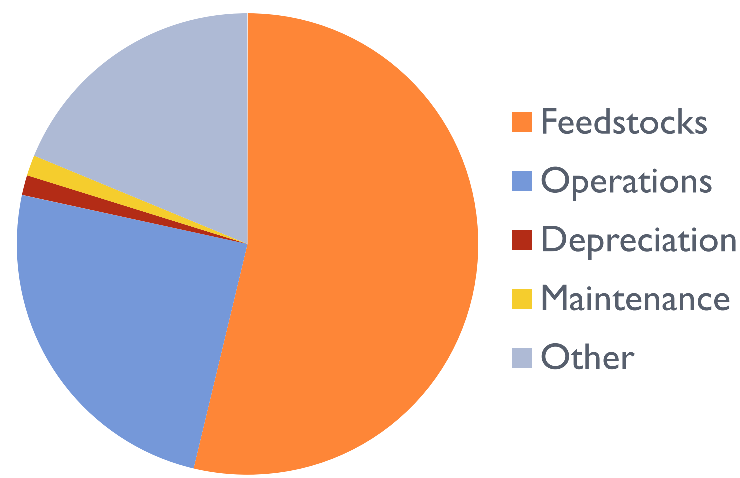
- **PP-MAH purchase**
  - C_{TCI}: $0.353 MM
    - Storage Tank: 37%
    - Working Capital: 49%
  - Annual Sales: $1.40 MM

- Annual Production Cost: $1.15 MM
  - 0.5 operators per shift
  - Feedstock costs comparable
- IRR: 80%
- Payback Period: ~2 years

Capital Costs



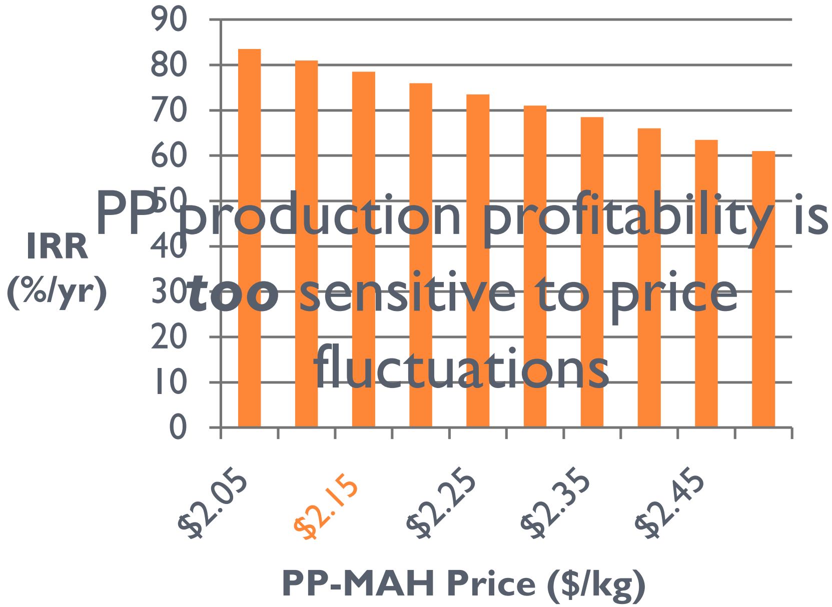
Annual Costs



PRICE SENSITIVITY

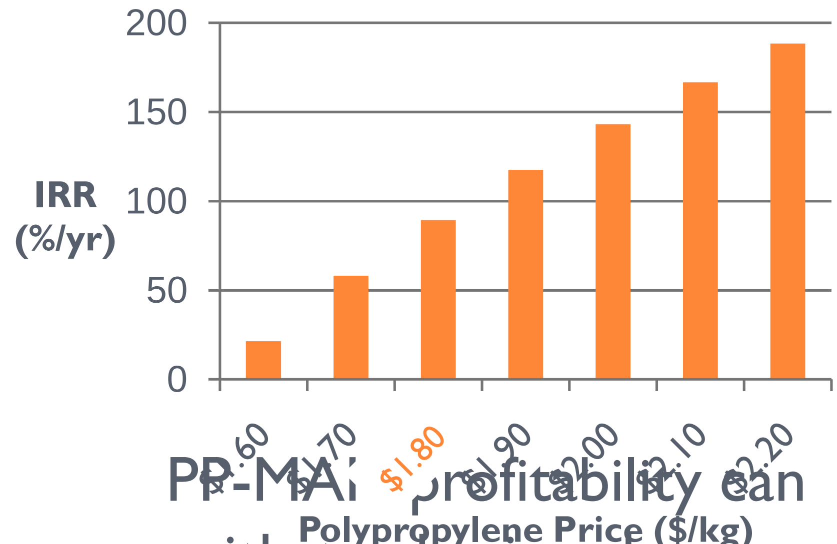
IRR as a function of …

- PP-MAH Purchase Price



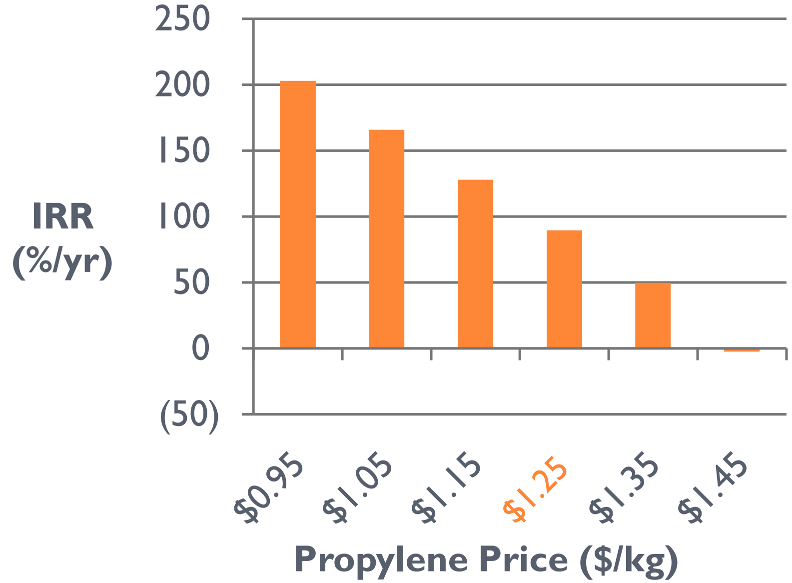
PP production profitability is **too** sensitive to price fluctuations

- PP Selling Price



PP-MAH profitability can withstand price changes

- Propylene Purchase Price



Summary & Recommendations

Scenario	C_{TCI} ($MM)	Annual Production Cost ($MM/yr)	Maximum Net Earnings ($MM/yr)	IRR (%/yr)	Approximate Payback Period (yr)	Risk
Spheripol + Grafting	41.7	245	19.6	93	0.5	High
Grafting Only	1.01	1.27	0.123	30	6	Low
PP-MAH Purchase	0.35	1.15	0.164	80	2	Low

Option 1

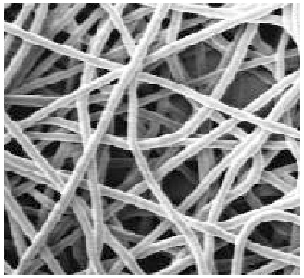
- Manufacture PP
- Graft with MAH

Option 2

- Purchase PP from Distributor
- Graft with MAH

Option 3

- Purchase PP-MAH from Distributor



Questions

- Thank you to Exide Technologies for sponsoring this project.