

Ports

Hydraulic Hybrids

Demonstration for Port Yard Hostlers

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U.S. Environmental Protection Agency



Clean Automotive Technology

www.epa.gov/otaq/technology

Good News Technology

- ✓ Clean Air
- ✓ Climate Change
- ✓ World Oil Consumption
- ✓ US Economy
- ✓ Fleet Operating Costs

This ALL AMERICAN HYBRID technology can bring about a significant contribution for meeting President Bush's goal to reduce U.S. fuel consumption by 20% in ten years.

What is this Port Project About?

EPA Goals

- ✓ Demonstrate cost-effective way(s) to reduce harmful diesel emissions
- ✓ Demonstrate effectiveness of hybrid technology throughout supply chain.

Four parts of EPA - working together

- ✓ Clean Ports USA (*National Clean Diesel Campaign*)
- ✓ Sustainable Ports and Carriers (*Office of International Affairs*)
- ✓ Northeast Diesel Collaborative (*EPA Region 1 and 2*)
- ✓ Clean Automotive Technology (*Office of Transportation and Air Quality*)



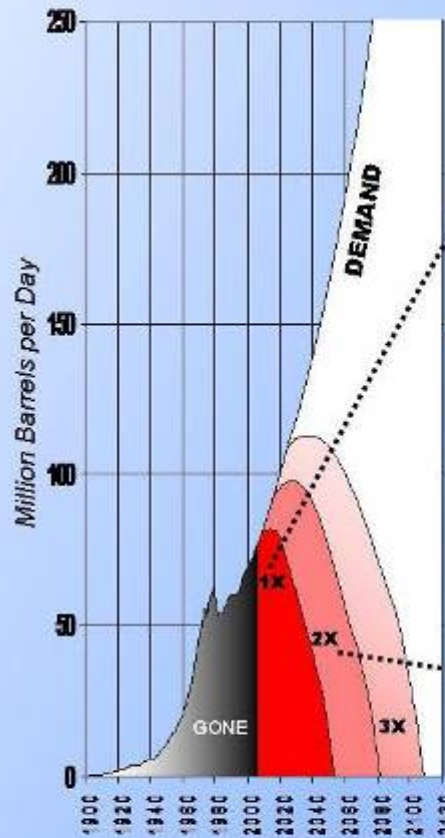
Ports

- ✓ Port Authority of New York/New Jersey
- ✓ APM Terminals North America

Industry

- ✓ Kalmar Industries
- ✓ Parker-Hannifin Corporation

Likely World Oil Production

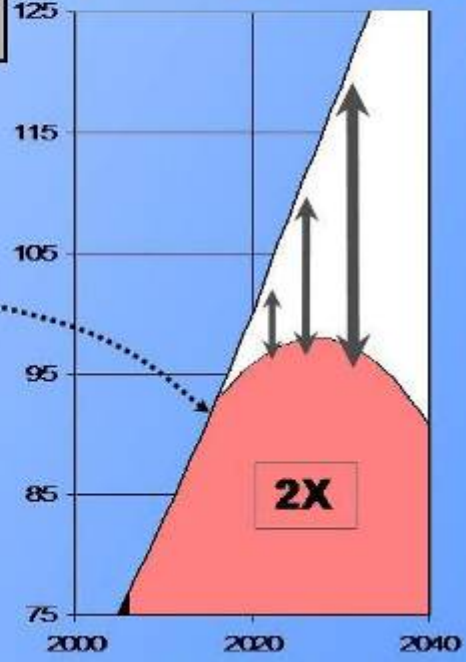
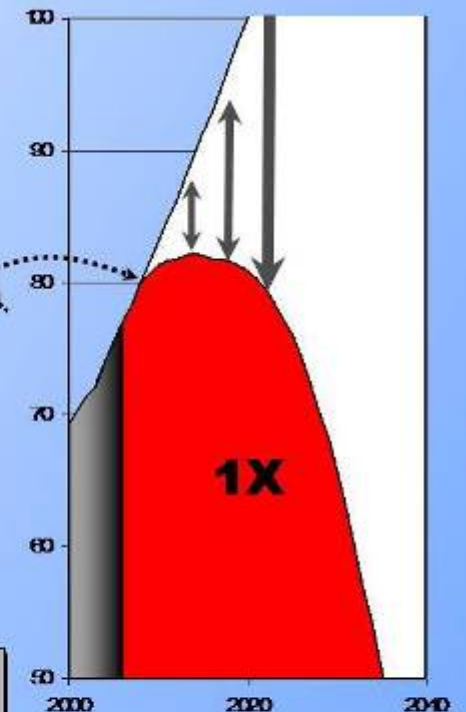


- Already Consumed
- Proven Reserves (EIA) →95%
- Double Proven Reserves →50%
- Triple Proven Reserves →5%

Demand assumes EIA's consumption growth rate of 1.9%

Gap in supply must be met by:

- Increased MPD
- Alternative Fuels
- Reduced VMT



What is a Hybrid?

A hybrid vehicle, in addition to its main engine, has a drivetrain that can recover and reuse energy.

(it has two on-board energy storage systems)

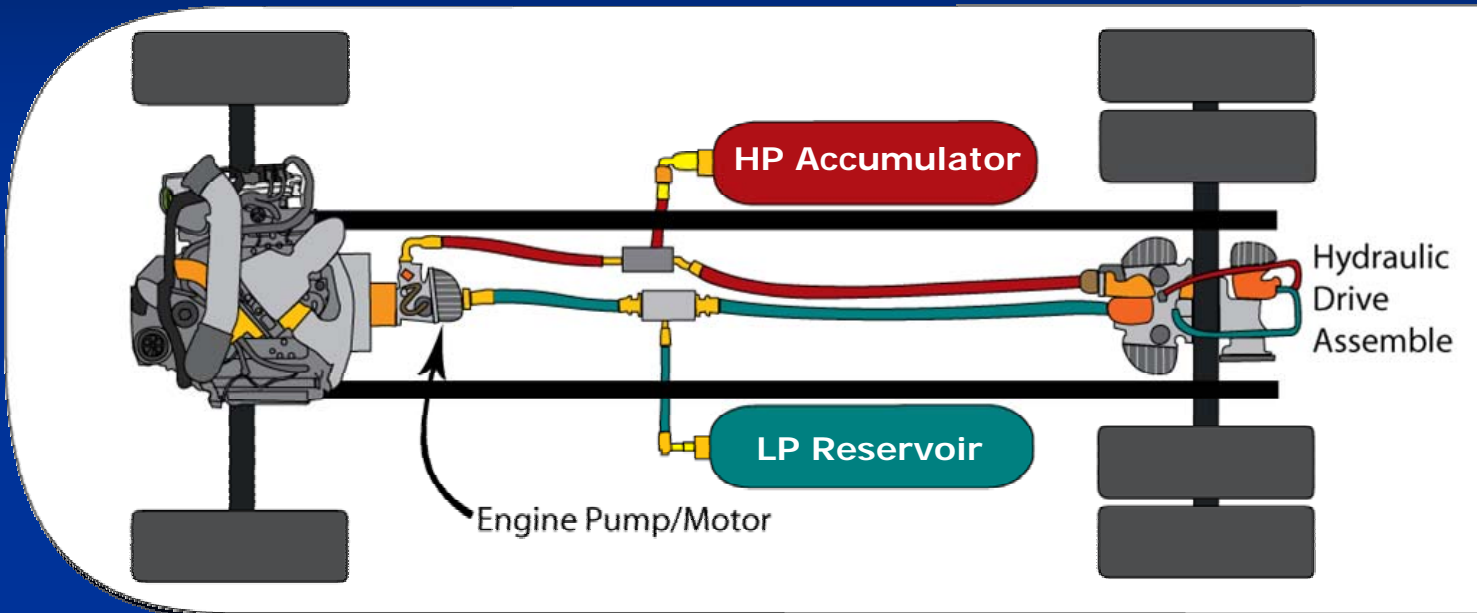
Hydraulic Hybrids

- Store energy in hydraulic accumulators
- Use hydraulic pump-motors

Electric Hybrids

- Store energy in batteries and/or ultra-capacitors
- Use electric generator-motors

Full Series Hydraulic Hybrid Truck Configuration



Why Series Hydraulic Hybrids?

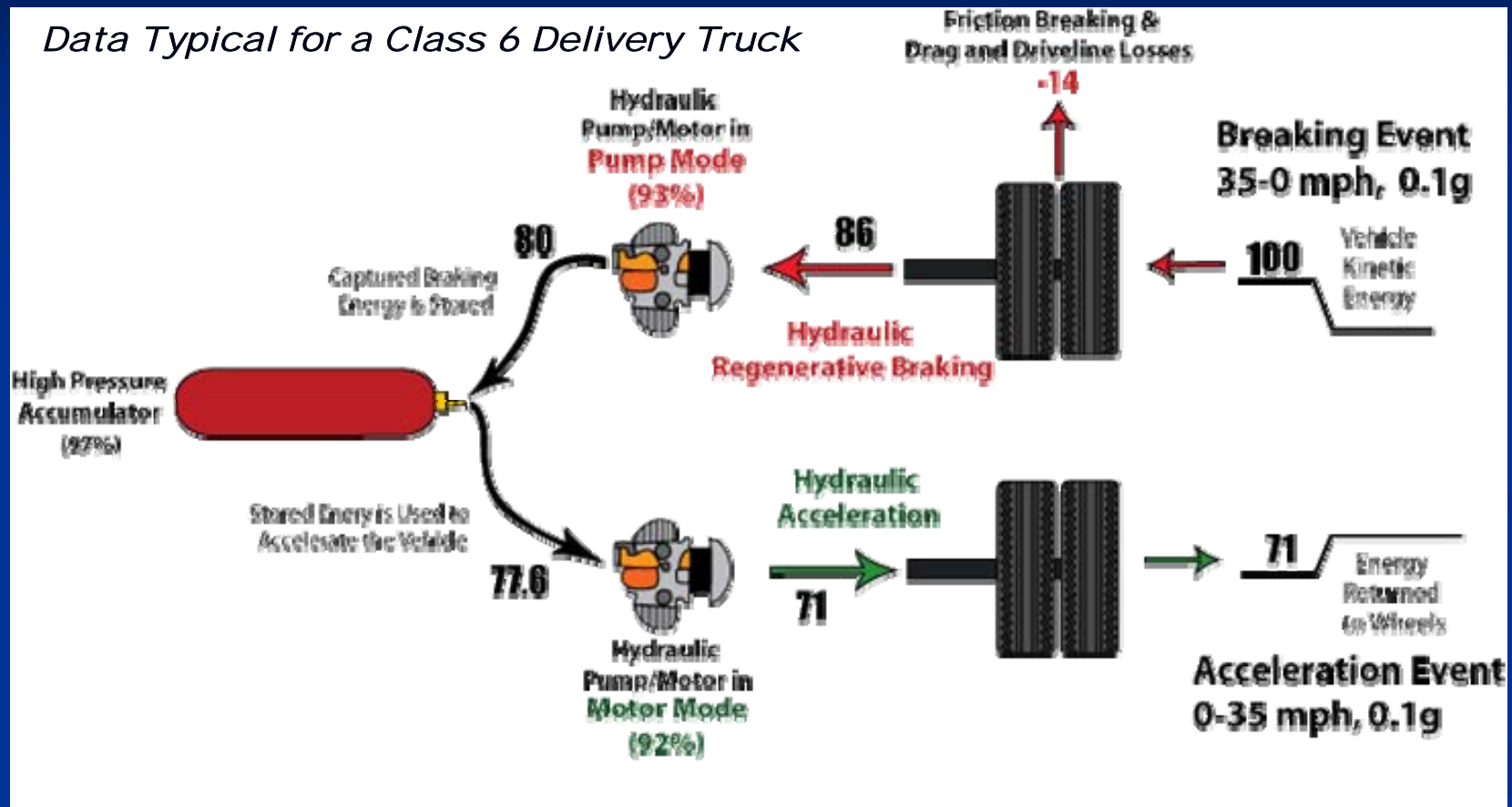
- ✓ **Highest possible fuel economy**
- ✓ **Lowest incremental cost**
 - Shortest payback to owner
 - Highest lifetime-savings
- ✓ **Ultra-low emissions**
- ✓ **Enables unique high-efficiency engines**

Strategies Which Increase Average Vehicle Efficiency

- 1. Capture and re-use energy normally lost to friction braking**
 - ✓ Regenerative Braking
- 2. Improve average efficiency of engine / drivetrain**
 - ✓ Operate engine at best efficiency
 - ✓ Shutoff engine at idle
 - ✓ Shutoff engine at all times when not needed

Efficiencies While Braking/Accelerating

Data Typical for a Class 6 Delivery Truck

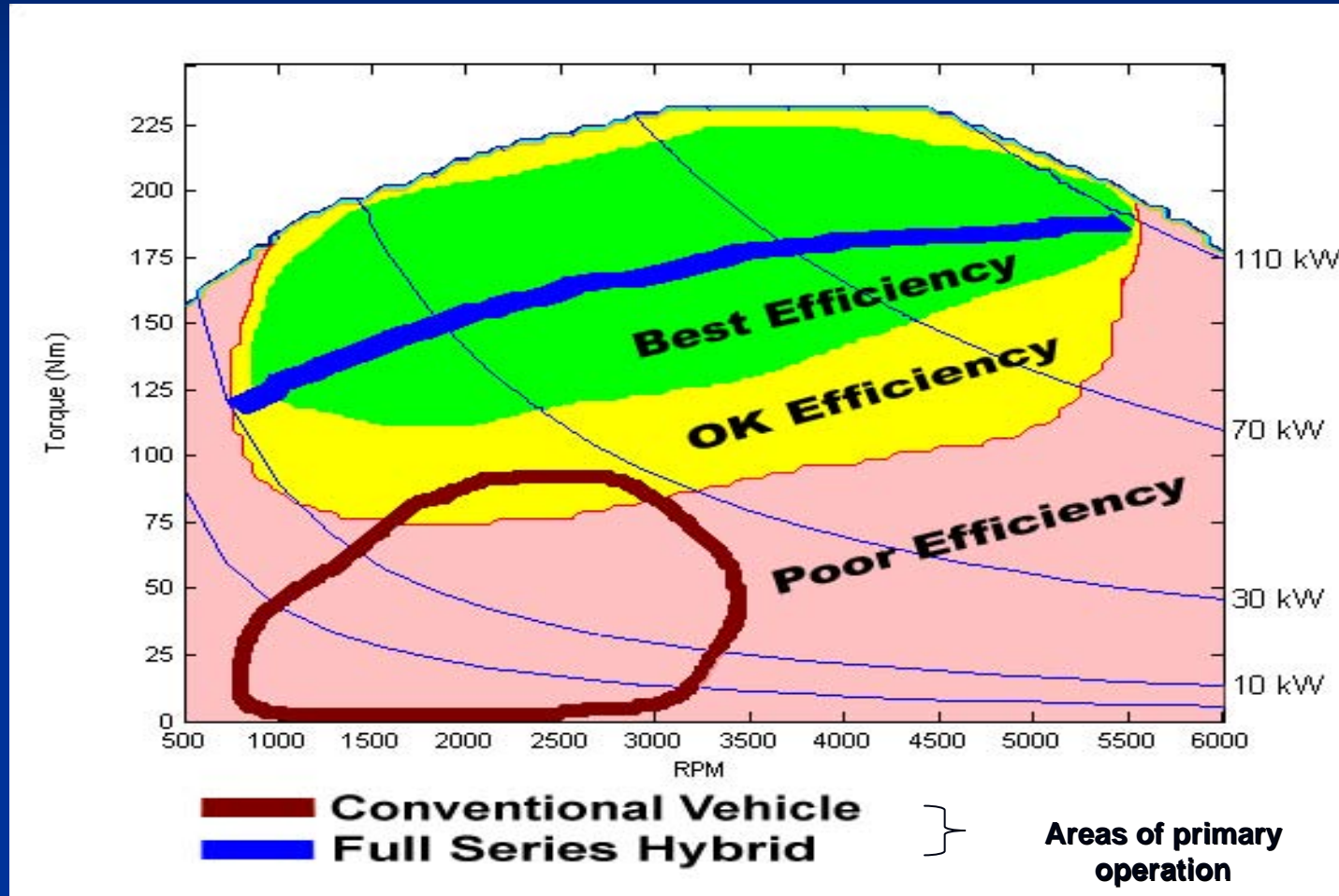


Analysis courtesy of Automotive Research Center – University of Michigan

Hydraulic Hybrids >70%

Electric Hybrids <25%

Power Map for a Typical Engine for Series Hybrids





Clean Automotive Technology

**Revolutionary
Engines**

**Revolutionary
Drivetrains**



**Ultra-Clean &
Ultra-Efficient Vehicles**



Focusing on unique, cost-effective technology

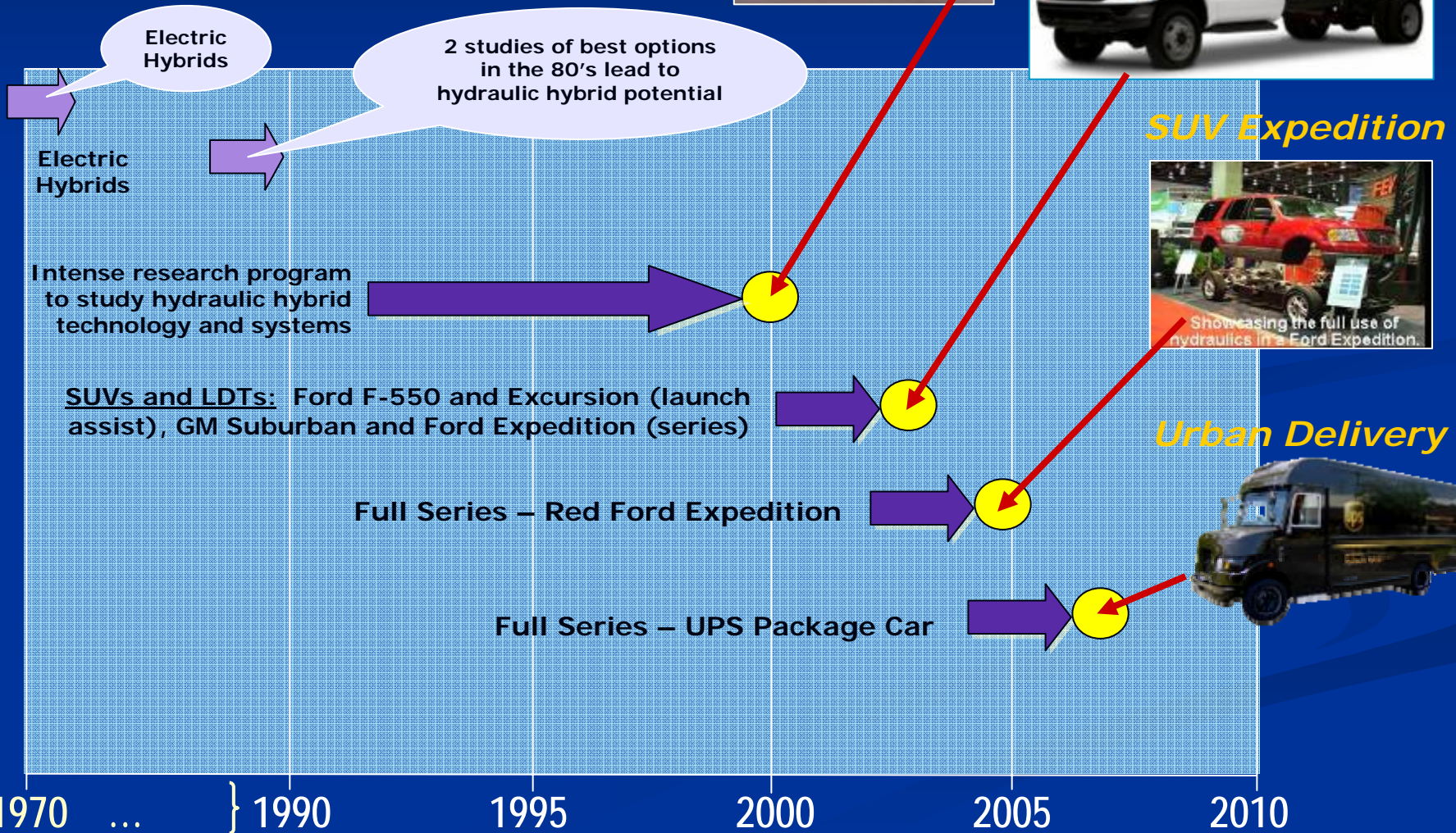
- Achieve ultra low pollution emissions
- Increase fuel efficiency
- Reduce greenhouse gases



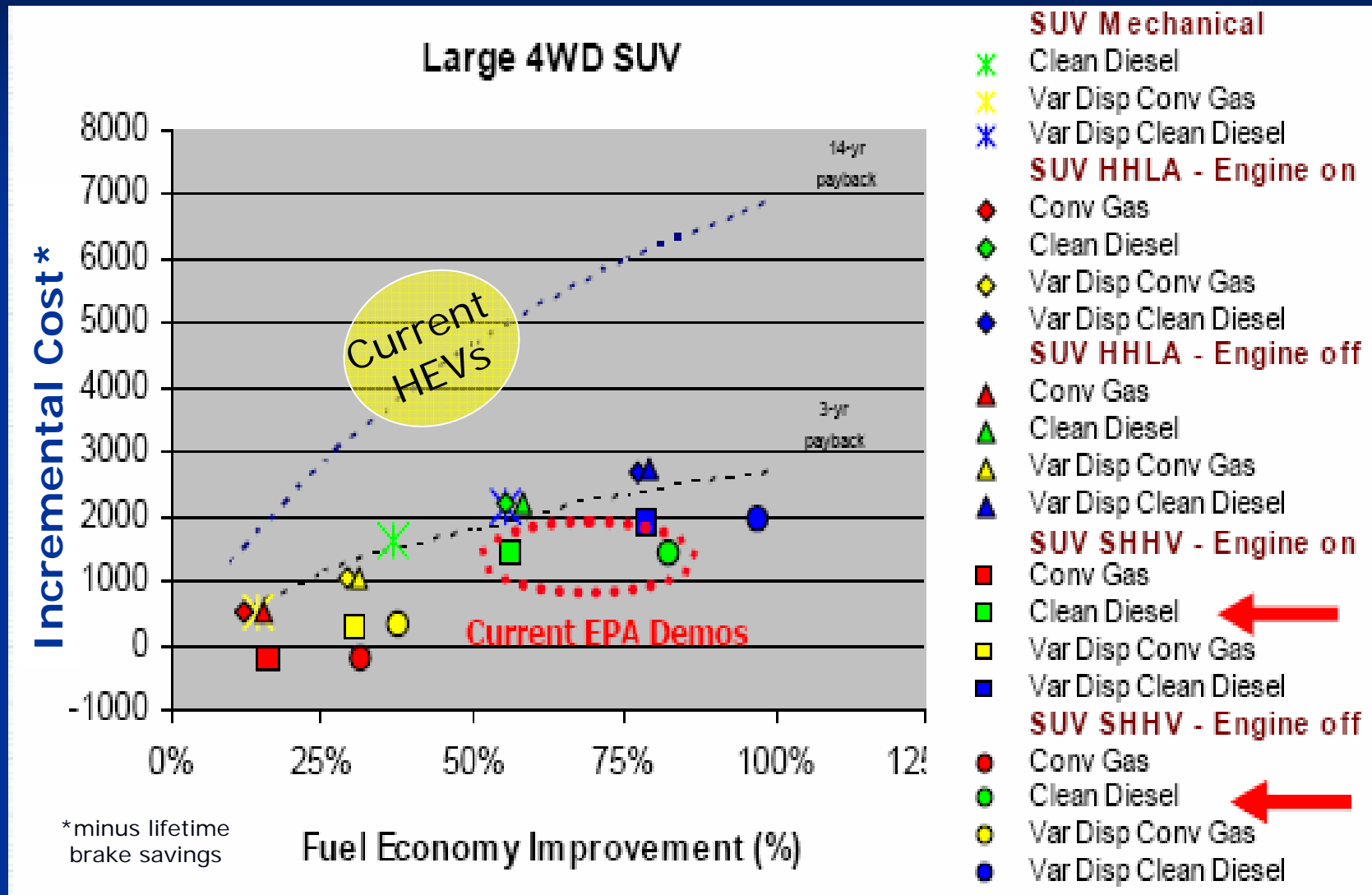
EPA Hydraulic Hybrid Timeline

Chassis 6 – Taurus size

F-550 Work Truck



Cost-Effective SUV Powertrains



Progress Report on Clean and Efficient Automotive Technologies Under Development at EPA - January 2004

www.epa.gov/otaq/technology

EPA's Full Series Hydraulic Hybrid Urban Delivery Vehicle

*Hydraulic Hybrid
UPS Package Car
Demonstration Creates
"Real World" Experience*



- 60-70% mpg improvement in city driving
- 2-3 year payback has attracts attention from fleets
- Potential for net Lifetime savings over \$50,000 with \$2.75/gal fuel costs
- Demonstration to accelerate technology transfer to industry & familiarity with technology
- Partners (UPS, Eaton, International Truck, US Army)

Fuel Economy Improvement

Summary of Initial Results



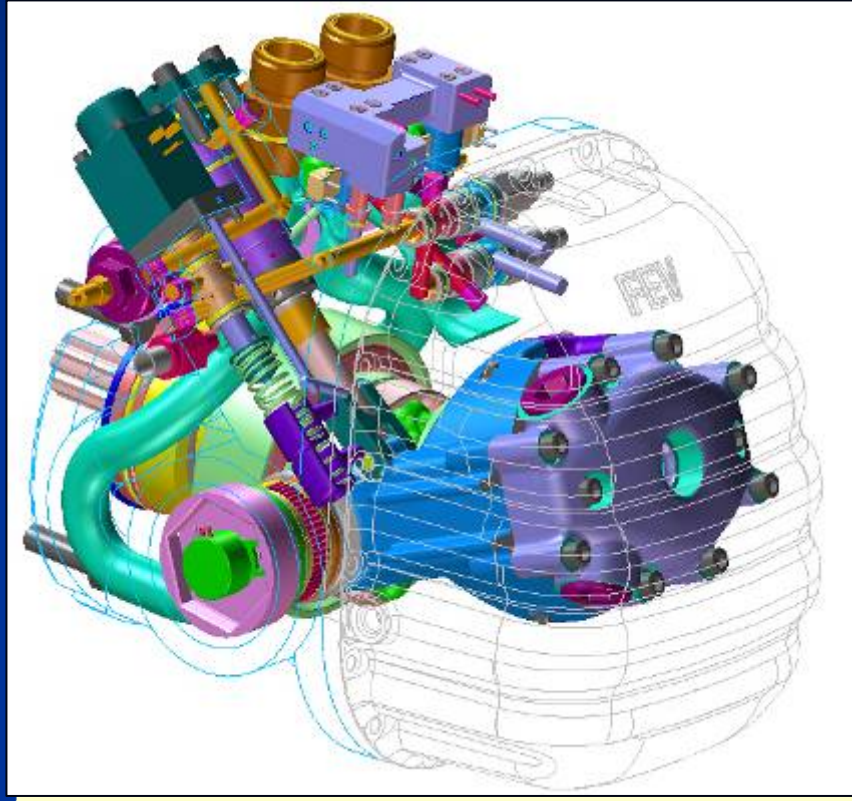
	MPG	Increase
Baseline Vehicle	10.4	---
Hydraulic Hybrid engine always running	14.4	39%
	15.0	44%
Hydraulic Hybrid engine-off when truck not moving	15.8	52%
	16.5	59%
Hydraulic Hybrid engine-off when truck decelerating or not moving	17.8	70%
	18.1	74%

Current Status of EPA's Hydraulic Hybrid Demonstration UPS Truck



- **Field tests** – Field testing began last fall in the Detroit area.
- **UPS very pleased with Results** – With how the vehicle performed, and with the fuel economy gains demonstrated in these early tests.
- **More testing of EPA demonstration truck** – Additional field testing is focusing on evaluating the performance characteristics of options for potential “pre-production” trucks.

Bent-Axis Pump-Motors

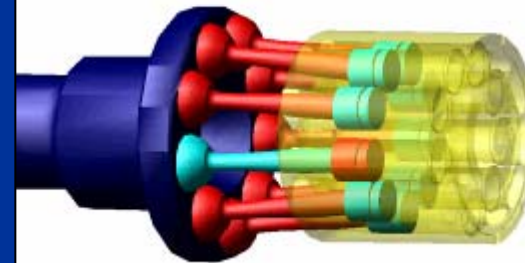


110cc pump-motor assembly

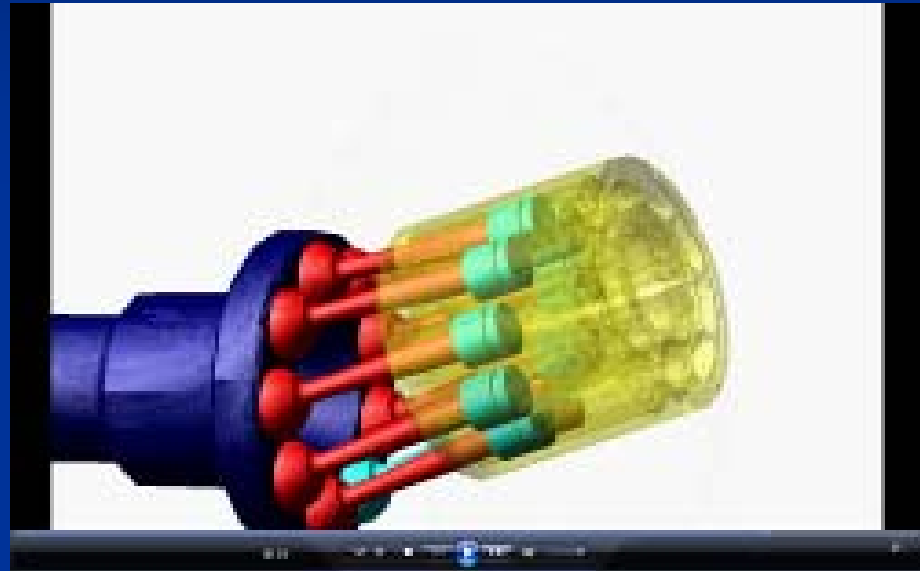
Yoke



Barrel



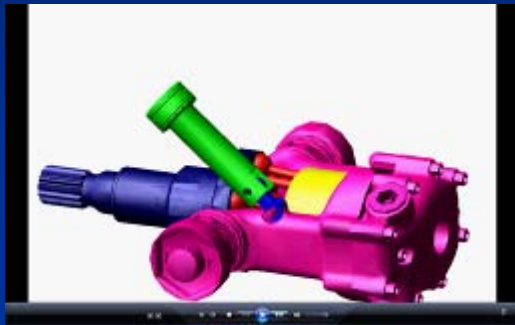
Power from the Pistons/Barrel



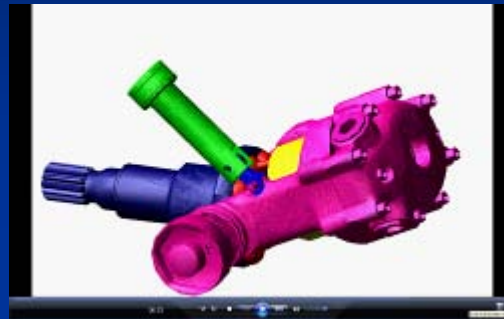
High power density capable of producing:

- ☑ 330 HP at 5000 psi at 45 deg.
- ☑ 510 HP at 7000 psi at 45 deg.

Adjustable to Power Demands Using Variable Position Yoke Assembly



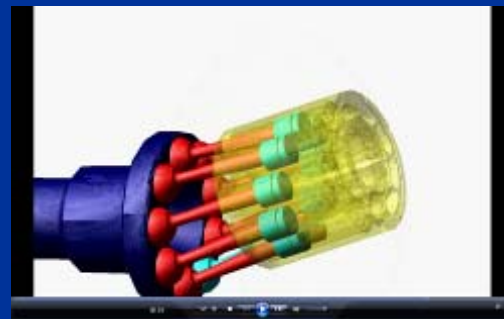
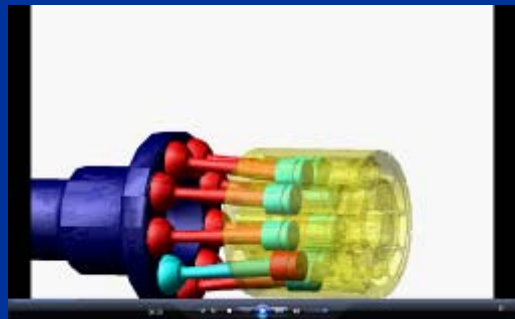
0 deg



22 deg



45 deg



- ✓ At 0 deg - no power produced or absorbed
- ✓ At 45 deg - max power produced or absorbed

Hydraulic Primary Drive Assembly Integrated into Rear Differential



Adding Accumulators for Energy Storage

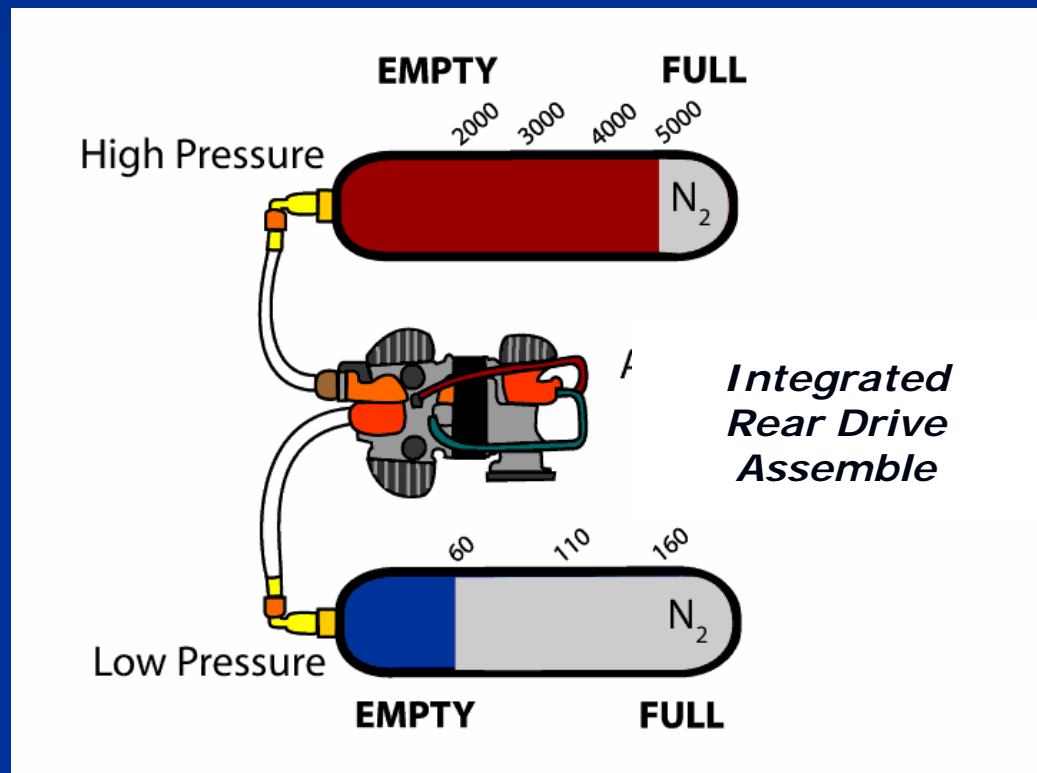
As hydraulic fluid enters either accumulator, the nitrogen (N_2) in that accumulator compresses and its pressure rises.

High Pressure

2000 to 5000 psi

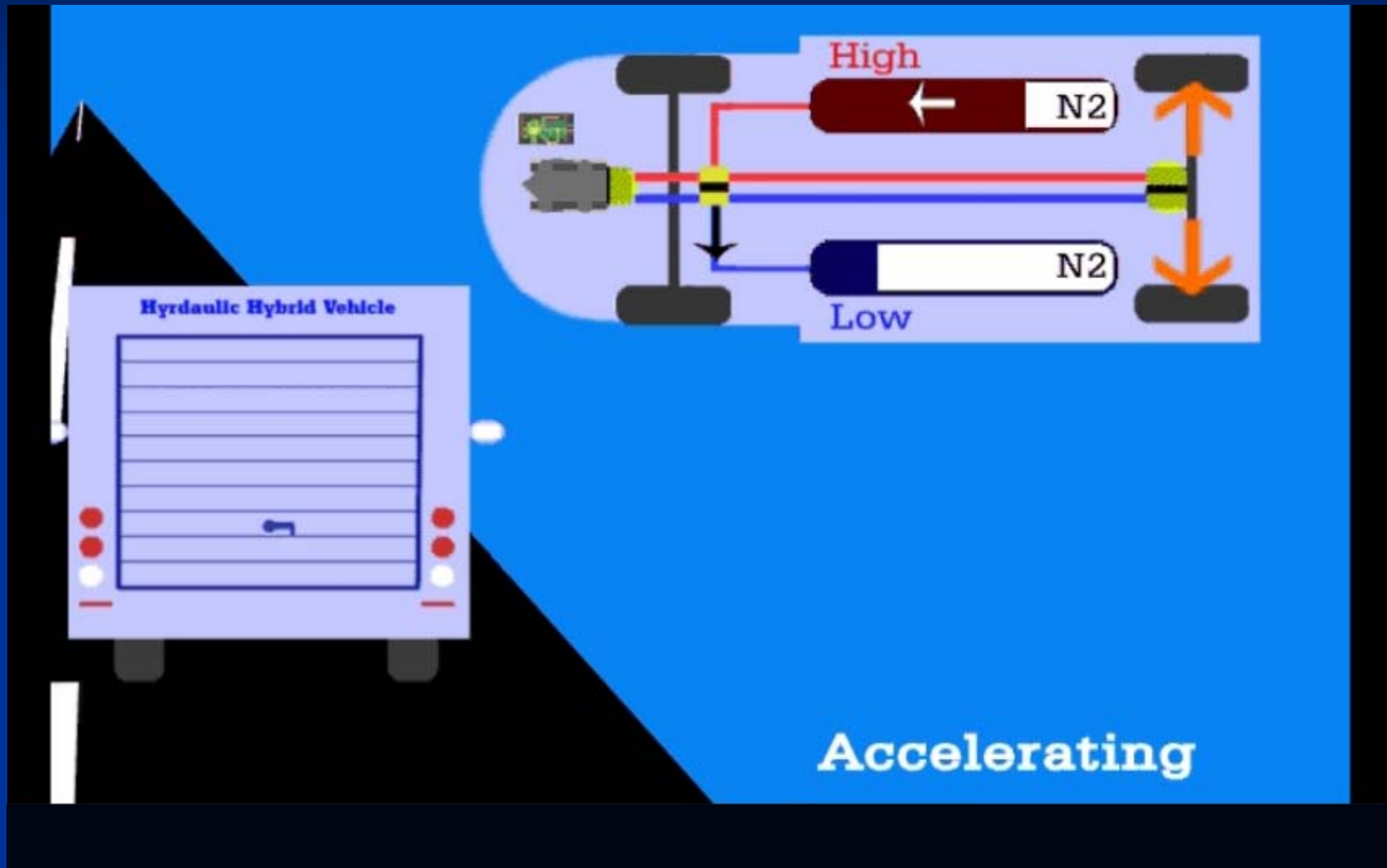
Low Pressure

60 to 160 psi

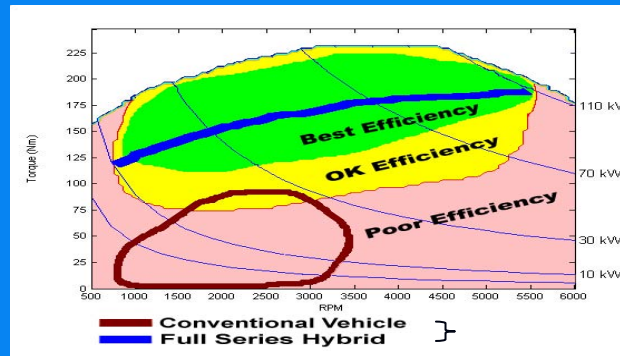


Future systems will utilize 7,000 psi

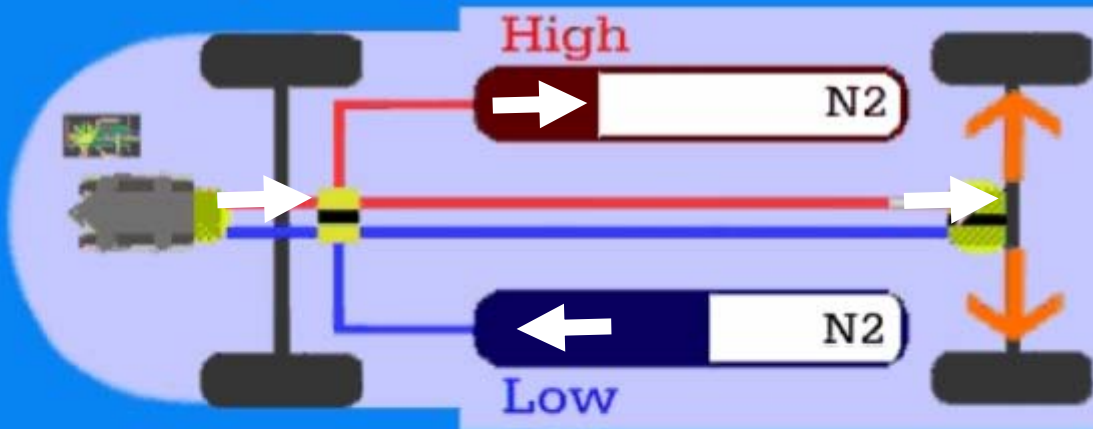
How it Works While Accelerating



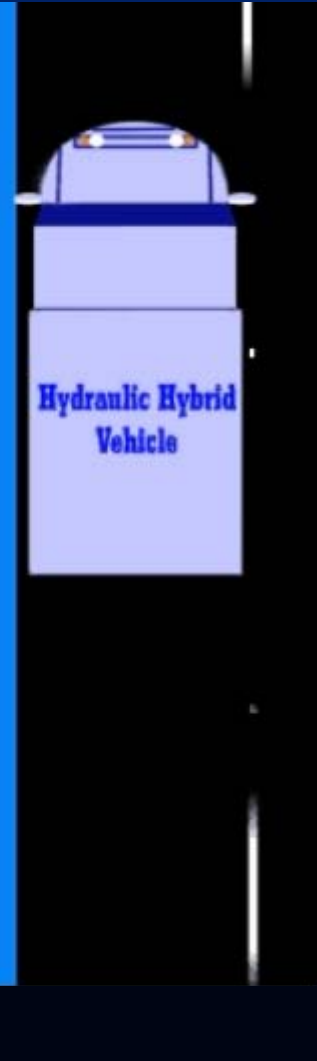
How it Works While Cruising



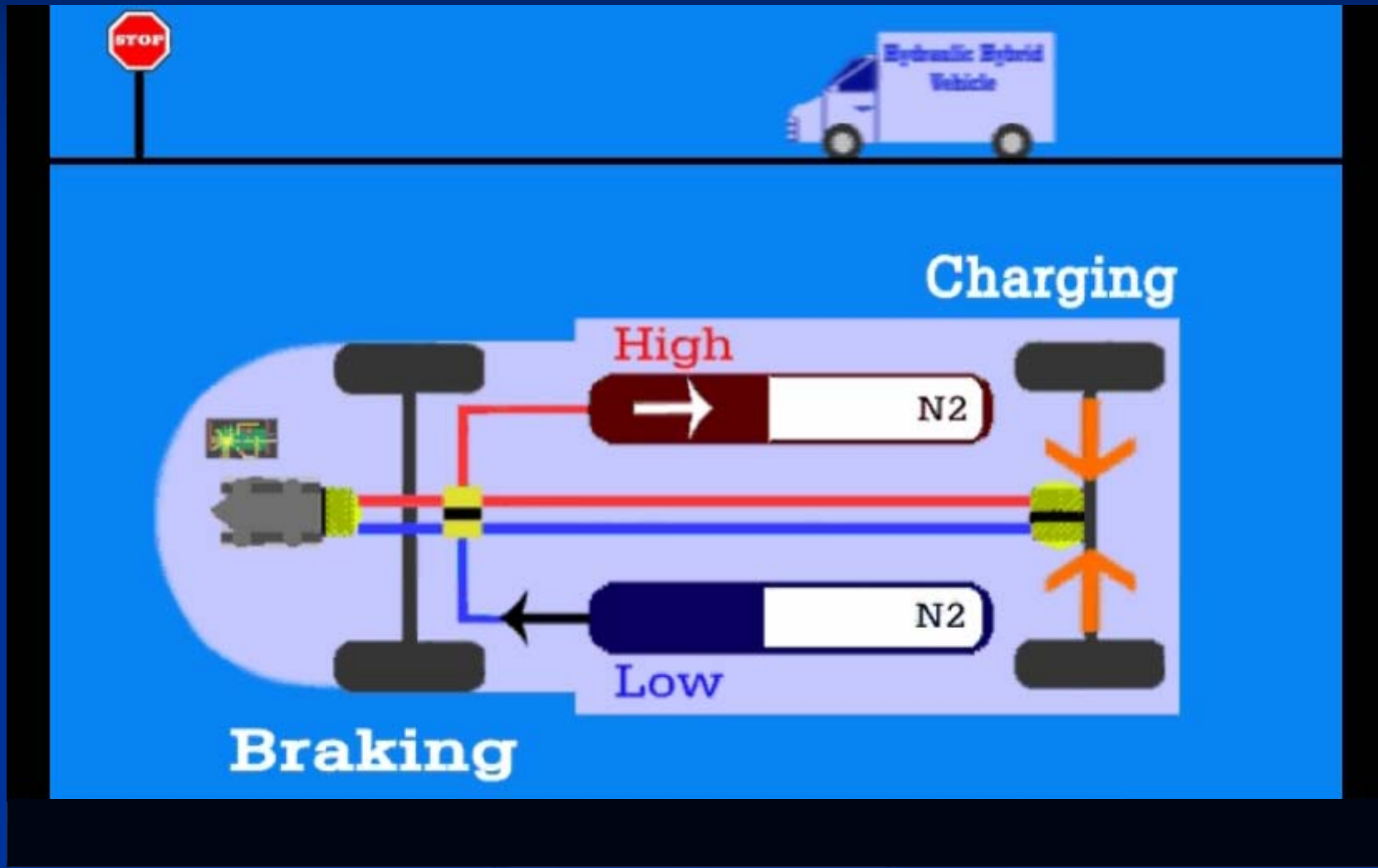
Engine ON



Cruising



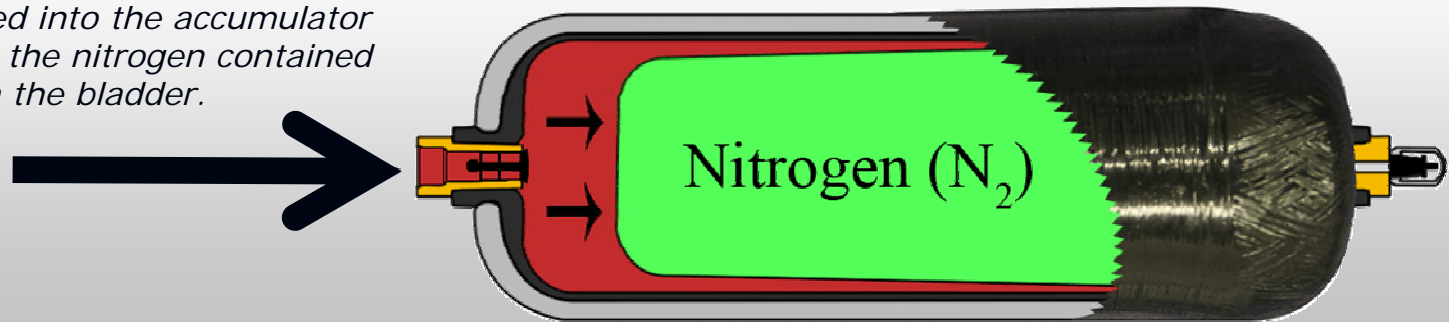
How it Works While Braking



Types of Accumulators

"Bladder" Style

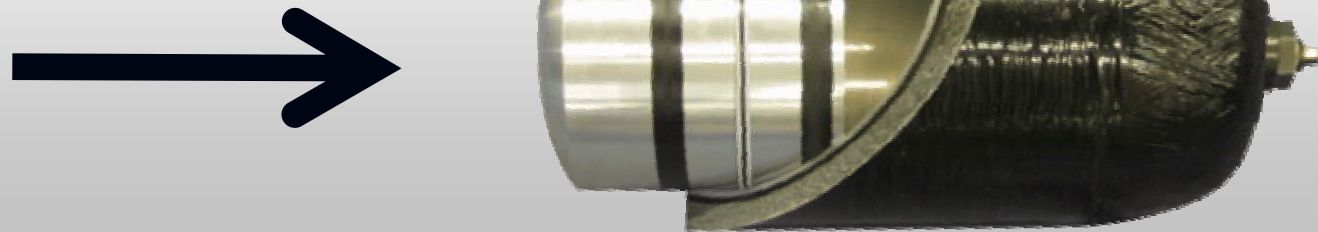
Fluid pumped into the accumulator compresses the nitrogen contained in the bladder.



A low pressure accumulator is pre-charged with fluid and nitrogen to about 60 psi.

"Piston-Shell" Style

Fluid pumped into the accumulator pushes the piston into the shell to compress the nitrogen.



A high pressure accumulator is pre-charged with fluid and nitrogen to about 2000 psi.

Accumulators for Hydraulic Hybrid Demonstration UPS Truck



**Rear
Wheel**

View looking at the driver's side of the vehicle

Demonstration UPS Truck Uses a 44-gallon System

- ✓ *20 gals of automatic transmission fluid*
- ✓ *High pressure operating between 2000 and 5000 psi*

This is Just the Beginning

Full Series Hydraulic Hybrids Create the Opportunity to use New High Efficiency Engines

Clean Diesel Combustion (CDC)

- No NOx Aftertreatment – EPA is working with International and Ford
- Effective use of DME

E85 (or M85) Fueled Engine

- Diesel efficiency levels (40%) from Ethanol or Methanol
- Engine costs similar to gasoline engines
- Supports US renewable fuel initiatives

High Efficiency Gasoline (HCCI)

- Homogenous Charge Compression Ignition
- Diesel efficiency levels (40%) from gasoline (Tier2 bin 2 emissions)
- Engine costs similar to gasoline engines

Direct Hydraulic Power (Free Piston Engine)

- High efficiency (40%) hydraulic power directly from a free piston – no crank

HyTEC –Hybrid Thermal Energy Converter

- Recovers energy from engine exhaust heat,
- Yields fuel cell efficiency levels at 1/5th the cost

Series Hydraulic Hybrid Yard Hostler Goals

1. To demonstrate **Best Possible Business Case** for hybrids to both manufacturers / suppliers and fleet customers
2. To show that series Hydraulic Hybrid Vehicles (HHV) have **highest efficiency** at the **lowest cost** potential
3. To definitively show that there are **no technical barriers** for series HHVs to become commercially viable



Series Hydraulic Hybrid Yard Hostler

Projected Benefits

*Hydraulic Hybrid Yard Hostler
Demonstration Creates
"Real World" Experience*

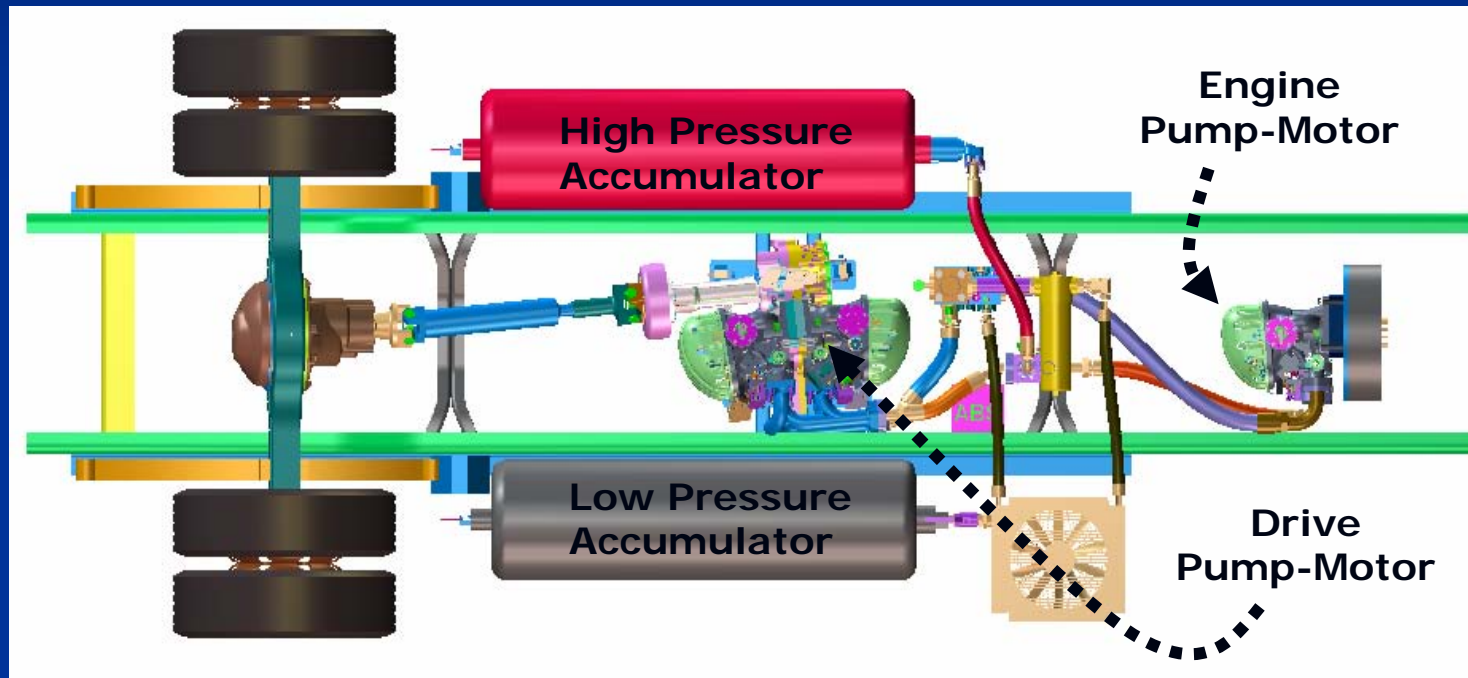


- 50-60% projected efficiency improvement in port operation (preliminary)
- Fuel savings \$23,000 with \$2.75/gal fuel costs (7 years for first owner)
- Demonstration to accelerate technology transfer to industry & familiarity with technology

Partners

- ✓ EPA (Region 2, OIA, and OTAQ-NVFEL)
- ✓ Port Authority of New York and New Jersey
- ✓ APM Terminals North America
- ✓ Parker-Hannifin Corporation and Kalmar Industries

Series Hydraulic Hybrid Yard Hostler Concept for Chassis Layout

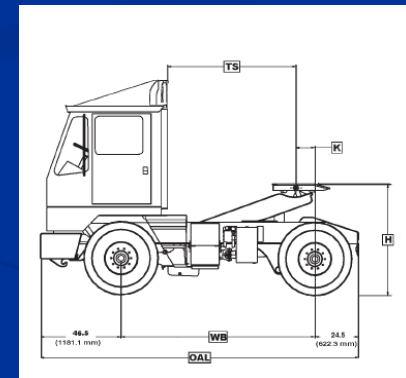


Benefits

- ✓ Reduced fuel consumption
- ✓ Reduced emissions
- ✓ Reduced engine on-time (no idling)
- ✓ Reduced brake wear

Differences From On-Road Class 6 Hydraulic Hybrid Vehicle

- ❑ 25 mph top speed
- ❑ Higher GVW
- ❑ Unique drive schedule
- ❑ Wheelbase shorter
- ❑ Air brakes & trailer brakes
- ❑ Cab air conditioning
- ❑ Packaging



Series Hydraulic Hybrid Yard Hostler Project Phases

- **Phase 1:** Planning Modeling, and Design
- **Phase 2:** Prototype Vehicle Development
- **Phase 3:** Pilot Operation, Emissions and Performance Testing, Business Case Assessment

Additional Information

✓ **Hydraulic Powertrains Propel These Hybrid Trucks**

Design News, June 2007

<http://designnews.com/article/CA6451735.html?nid=3077&rid=1294693122&>

✓ **Hydraulic Hybrid Promises Big Savings for UPS**

Hydraulics and Pneumatics, October 2006

<http://www.hydraulicspneumatics.com/200/Issue/Article/False/38545/Issue>

✓ **EPA Delivers with Fully Hydraulic Hybrid Truck**

Hydraulics and Pneumatics, October 2005

<http://www.hydraulicspneumatics.com/200/Issue/Article/False/11985/>

✓ **Progress Report on Clean and Efficient Automotive Technologies Under Development at EPA - January 2004**

<http://www.epa.gov/otaq/reports/adv-tech/420r04002.pdf>

✓ **EPA's Clean Automotive Technology**

John Kargul 734-214-4386, <http://www.epa.gov/otaq/technology/#hydraulic>

✓ **EPA's National Clean Diesel Campaign**

Trish Koman 734-214-4955, <http://www.epa.gov/cleandiesel/ports>

