

Ports

Hydraulic Hybrids

Demonstration for Port Yard Hostlers

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*John J. Kargul, Director of Technology Transfer
Advanced Technology Division*

*Office of Transportation and Air Quality
U.S. Environmental Protection Agency*



Clean Automotive Technology

www.epa.gov/otaq/technology

What is this Port Project About?

EPA Goals

1. To demonstrate cost-effective way(s) for Ports to reduce harmful diesel emissions
2. To provide a technology project of interest to both the Ports of NY/NJ and Rotterdam

Four parts of EPA - working together

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





National Clean Diesel Campaign

Two components:

- **Regulatory:** Clean Air Act requirements for new engines/fuels
- **Innovative Strategies:** Existing engines in legacy fleet

Goal: *Reduce emissions from the legacy fleet of over 11 million diesel engines by 2014*

- About 500 projects nationwide (~130 EPA grants since 2003)
- About 250,000 engines retrofitted or replaced
- ~ 25 emissions control technologies verified, more on California's list
- Partners have contributed significant resources
 - Over 2 external dollars for every 1 federal dollar invested
 - States have established programs with funding > \$400M



Clean Ports USA

EPA's national program to encourage reductions in diesel emissions at ports

- Identifying incentives to overcome barriers to voluntary action to improve public health and reduce fuel consumption
- Seeking cost-effective emission reductions from all diesel equipment in and around marine ports
- Working through the Regional Clean Diesel Collaboratives



CLEANPORTSUSA
SVE



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



What is a Hydraulic Hybrid?

- *A hybrid vehicle, in addition to its main engine, has a drivetrain that can recover and reuse energy*
 - ✓ A different kind of transmission, one that can recover, store and reuse power hydraulically (rather than electrically)
 - ✓ An energy storage system
 - ✓ A hydraulic drive system to convert the stored energy to motive power

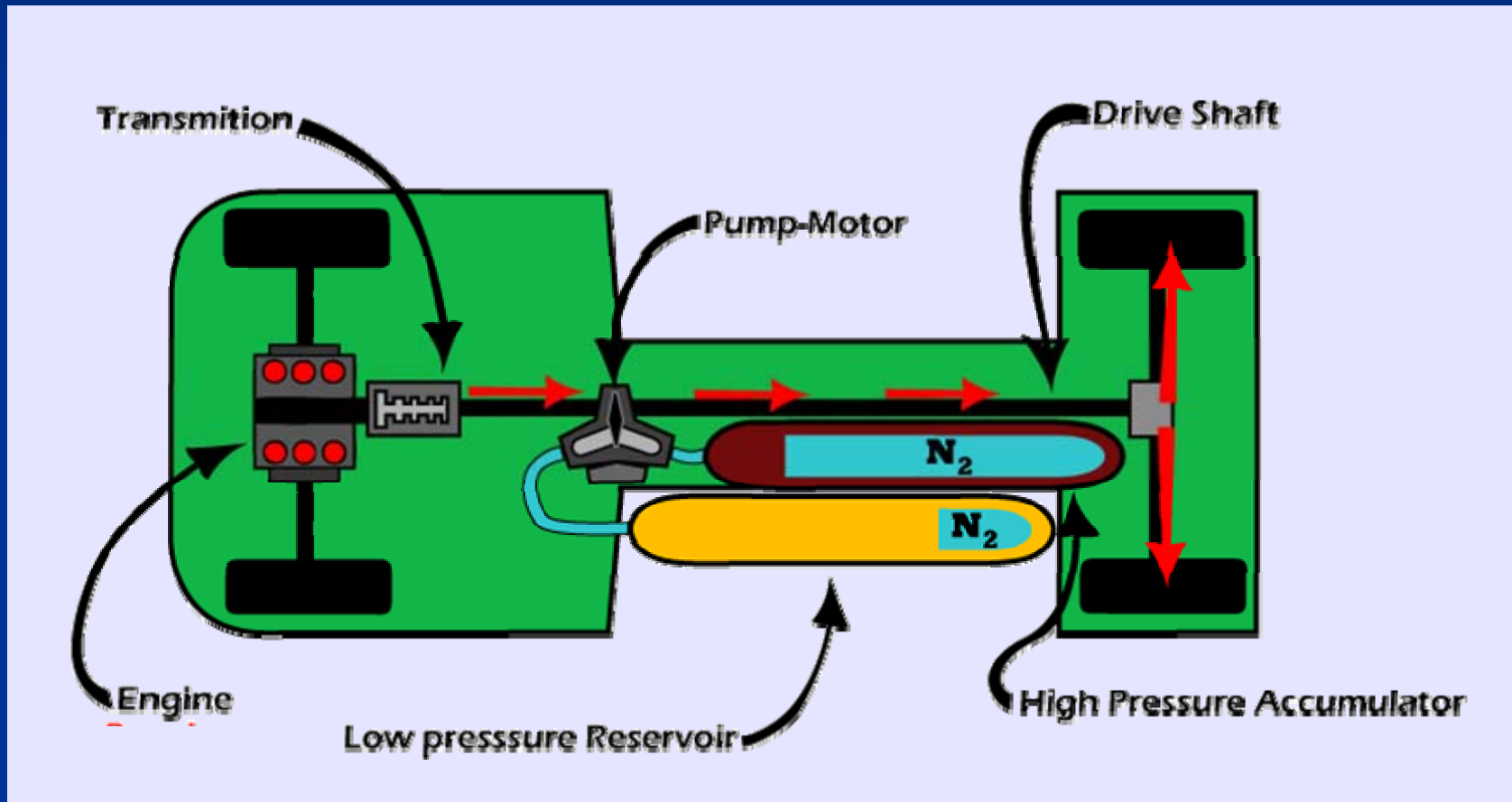
Hydraulic Hybrids

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

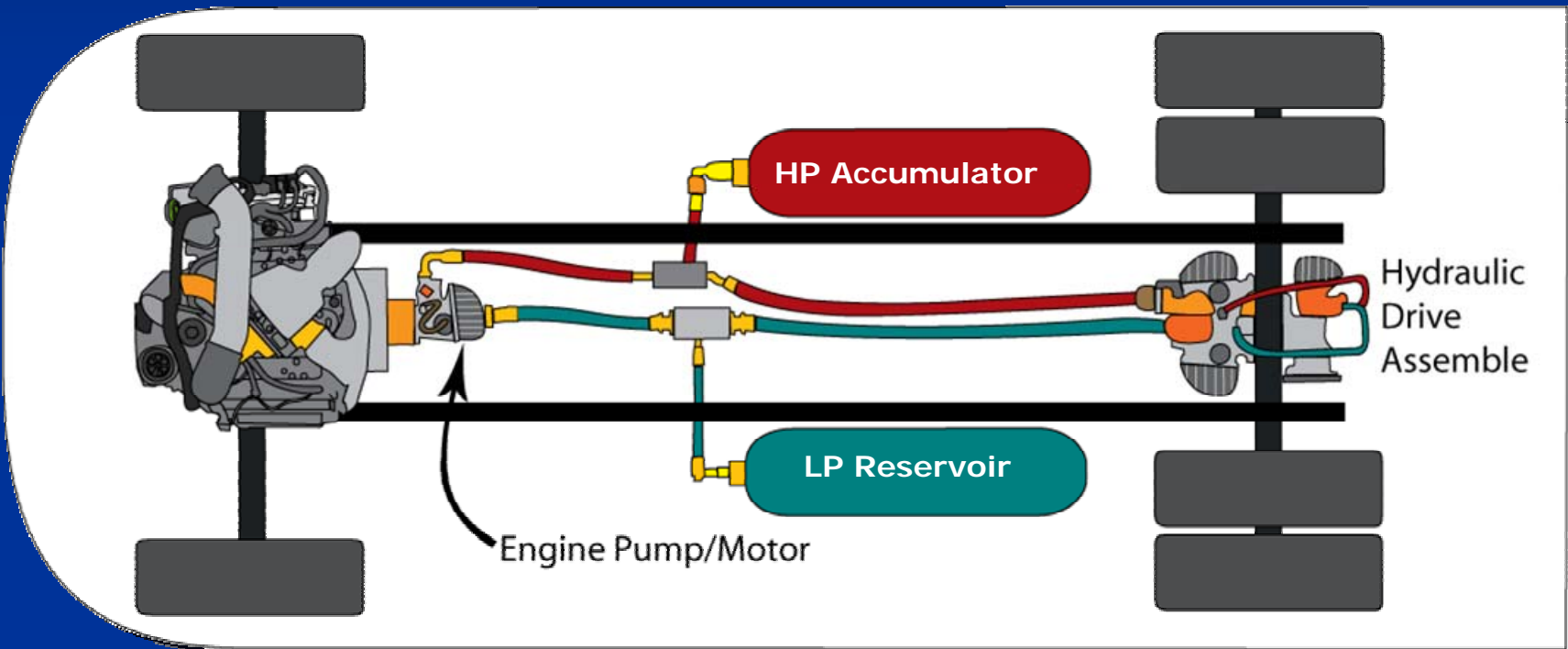
Electric Hybrids

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

Parallel Hydraulic Hybrid Truck Configuration



Full Series Hydraulic Hybrid Truck Configuration



Why Series Hydraulic Hybrids?

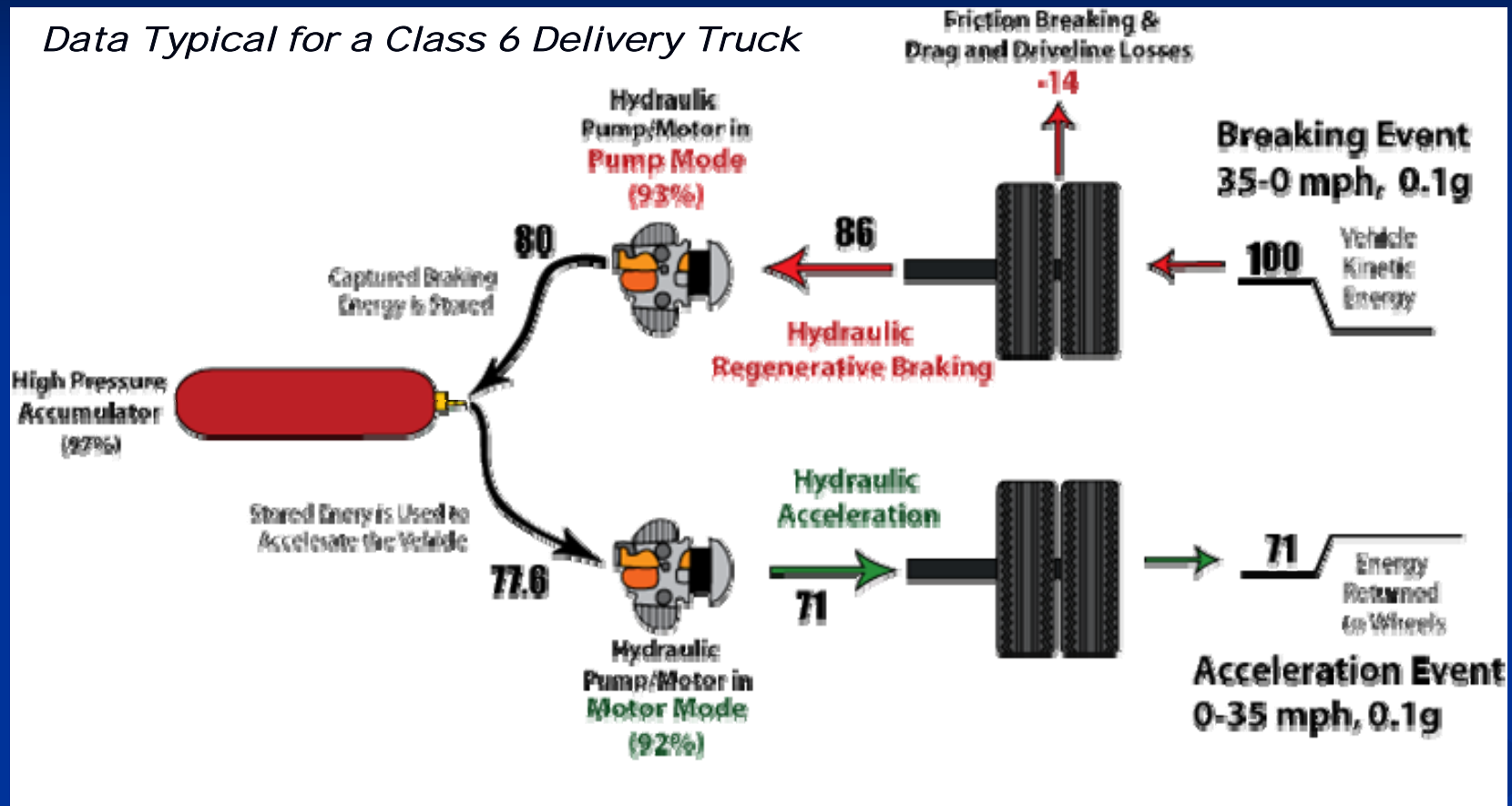
- ✓ **Highest possible fuel economy**
- ✓ **Lowest incremental cost**
 - Shortest payback to owner
 - Highest lifetime-savings
- ✓ **Enables unique high-efficiency engines**
- ✓ **Ultra-low emissions**

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

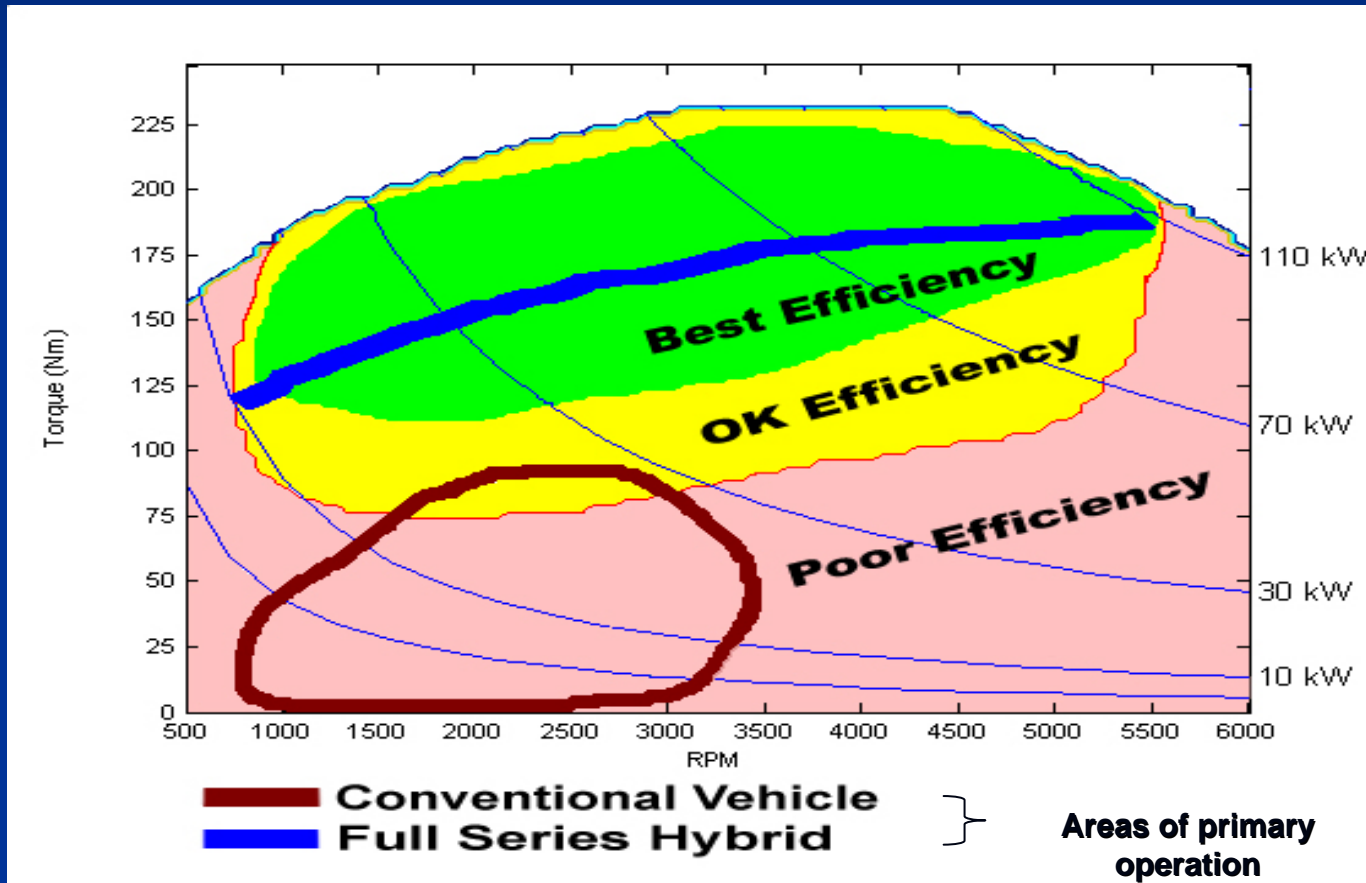


Analysis courtesy of Automotive Research Center – University of Michigan

Hydraulic Hybrids >70%

Electric Hybrids <25%

Power Map for a Typical Engine for Series Hybrids



EPA Hydraulic Hybrid Timeline

Chassis 6 – Taurus size

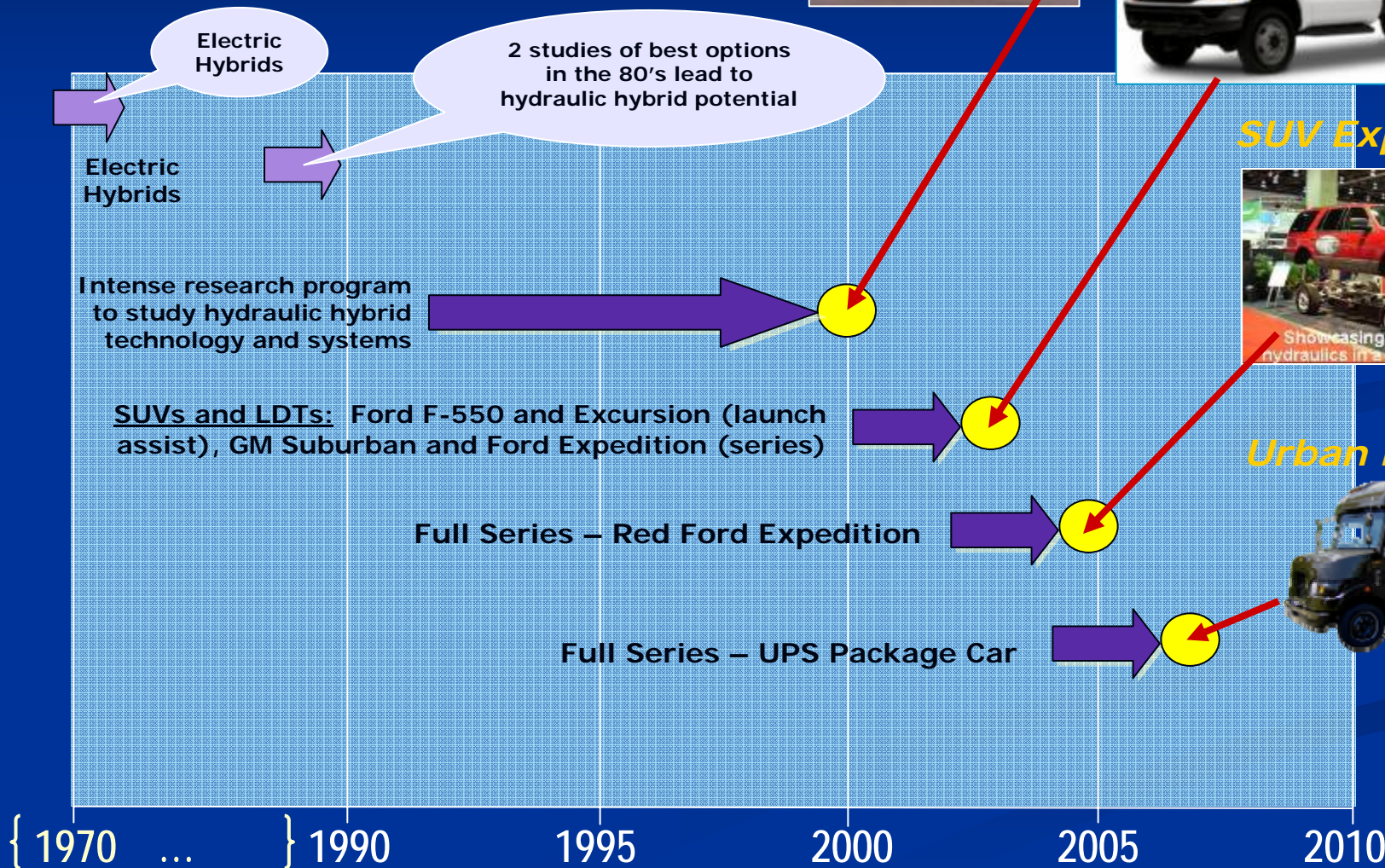
F-550 Work Truck



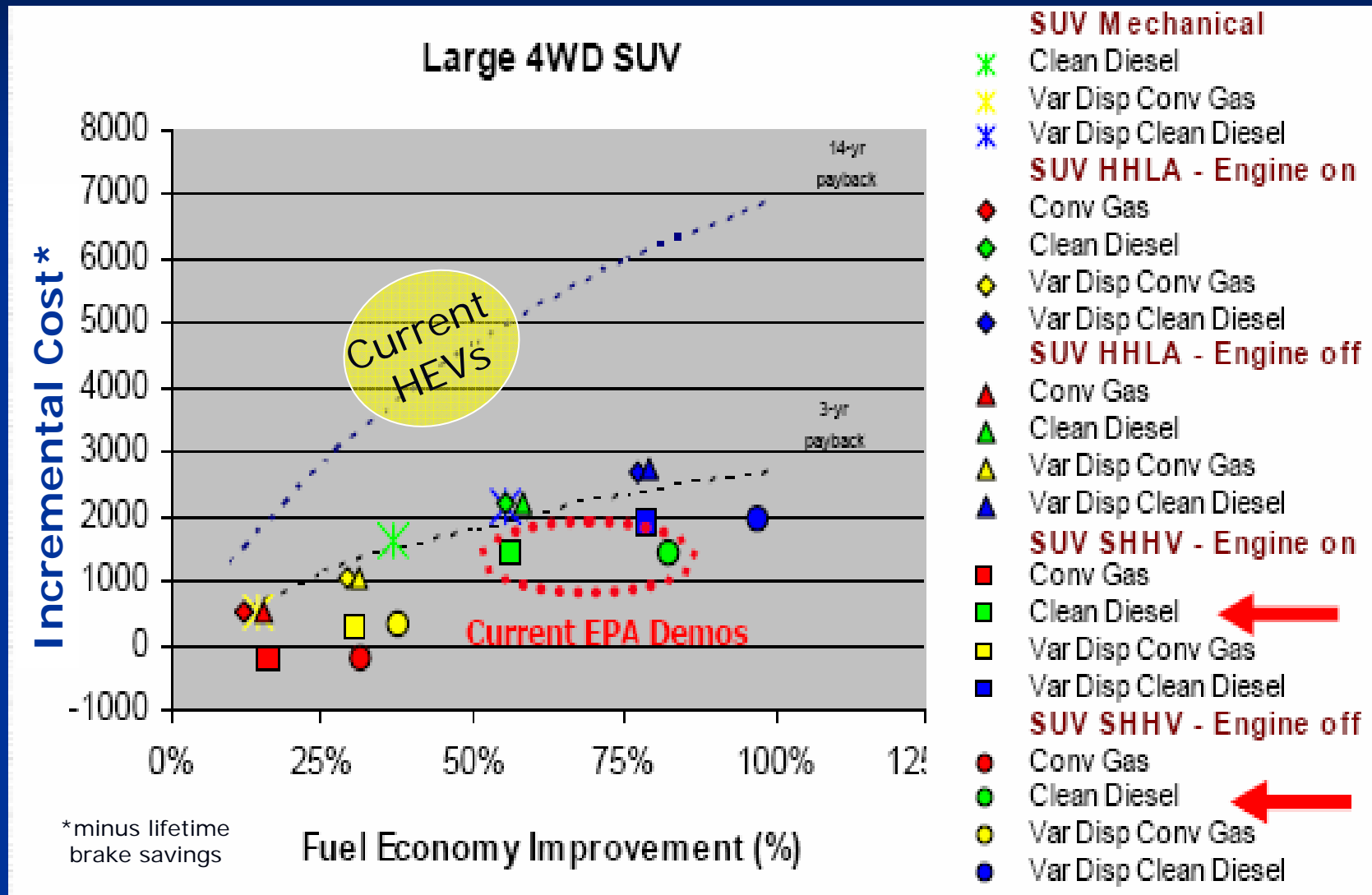
SUV Expedition



Urban Delivery



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



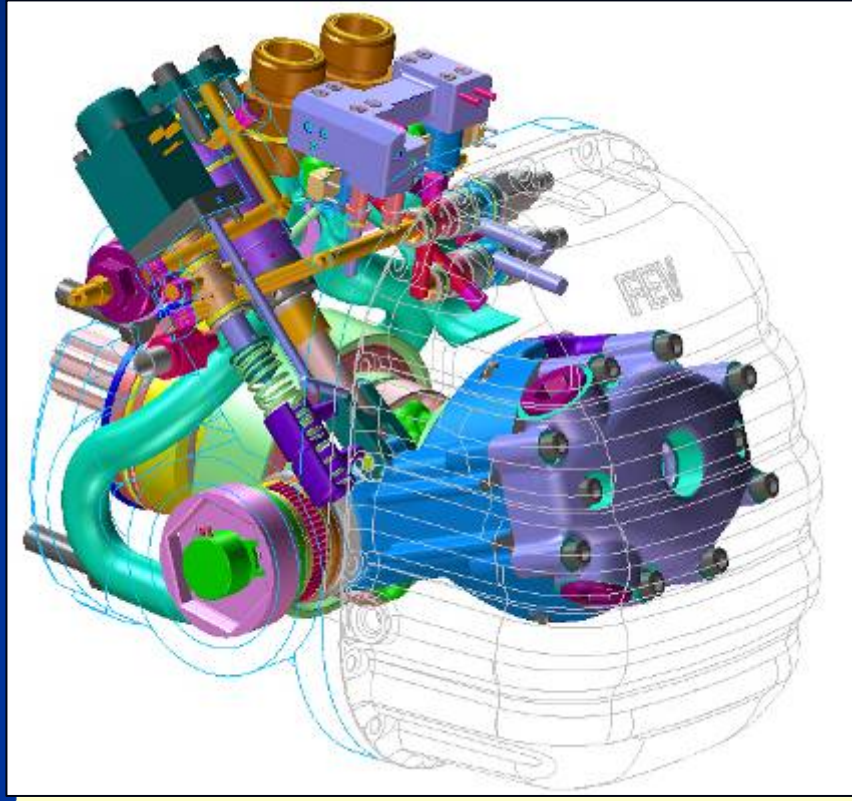
	MPG	Increase
Baseline Vehicle	10.4	---
Hydraulic Hybrid engine always running	14.4	39%
	15.0	44%
Hydraulic Hybrid engine-off when truck not moving	15.8	52%
	16.5	59%
Hydraulic Hybrid engine-off when truck decelerating or not moving	17.8	70%
	18.1	74%

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

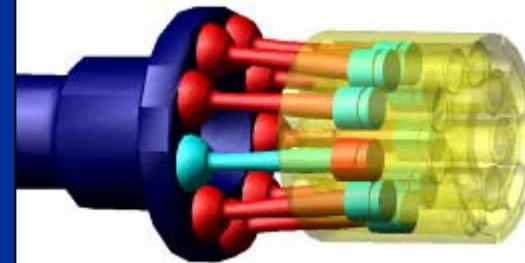


110cc pump-motor assembly

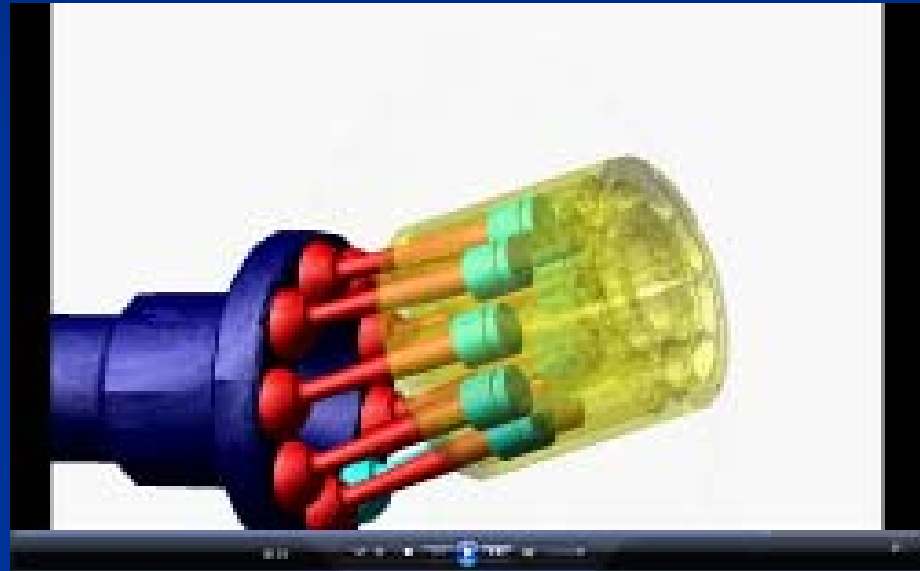
Yoke



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.

Hydraulic Primary Drive Assembly Integrated into Rear Differential



Adding Accumulators for Energy Storage

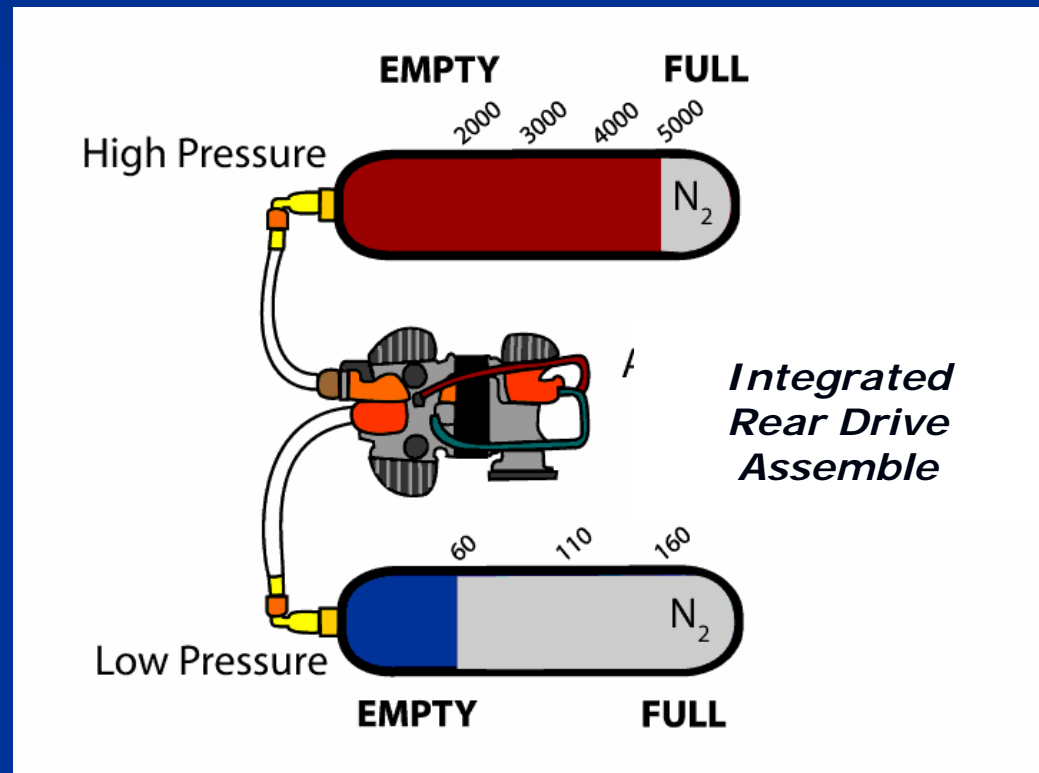
As hydraulic fluid enters either accumulator, the nitrogen (N_2) in that accumulator compresses and its pressure rises.

High Pressure

2000 to 5000 psi

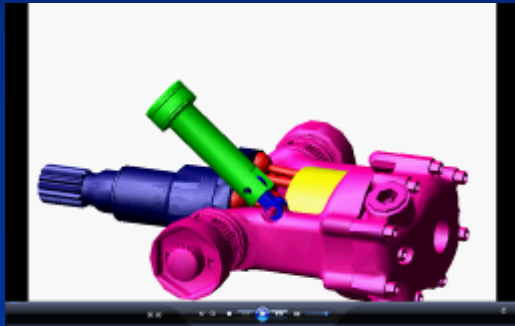
Low Pressure

60 to 160 psi

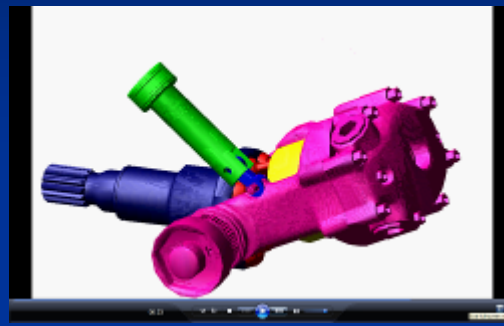


Future systems will utilize 7,000 psi

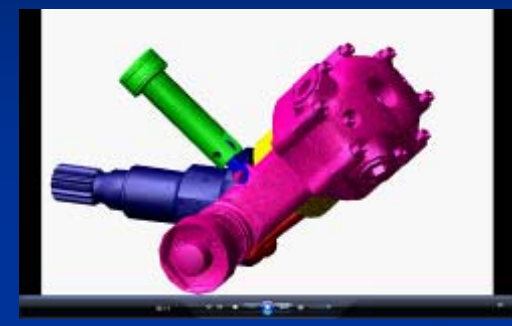
Adjustable to Power Demands Using Variable Position Yoke Assembly



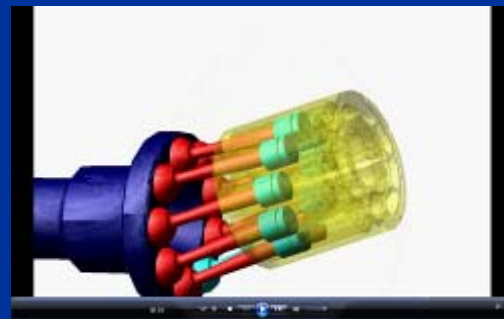
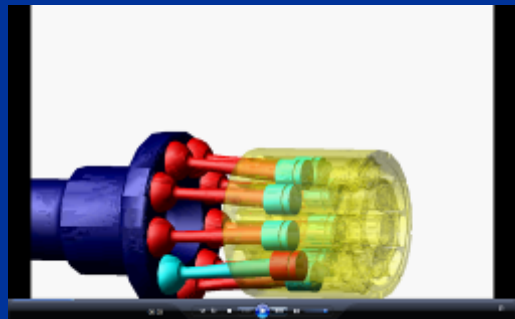
0 deg



22 deg

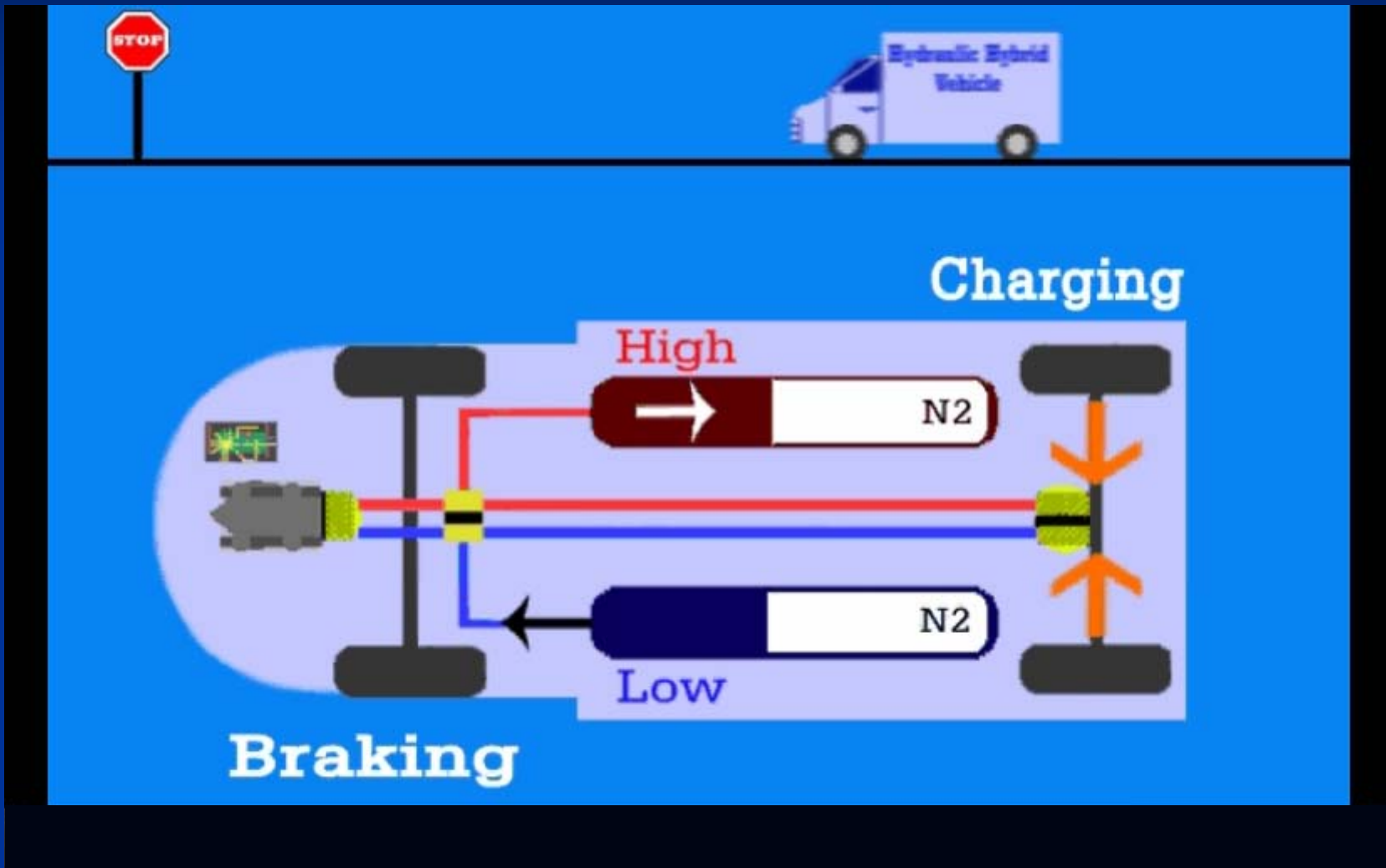


45 deg

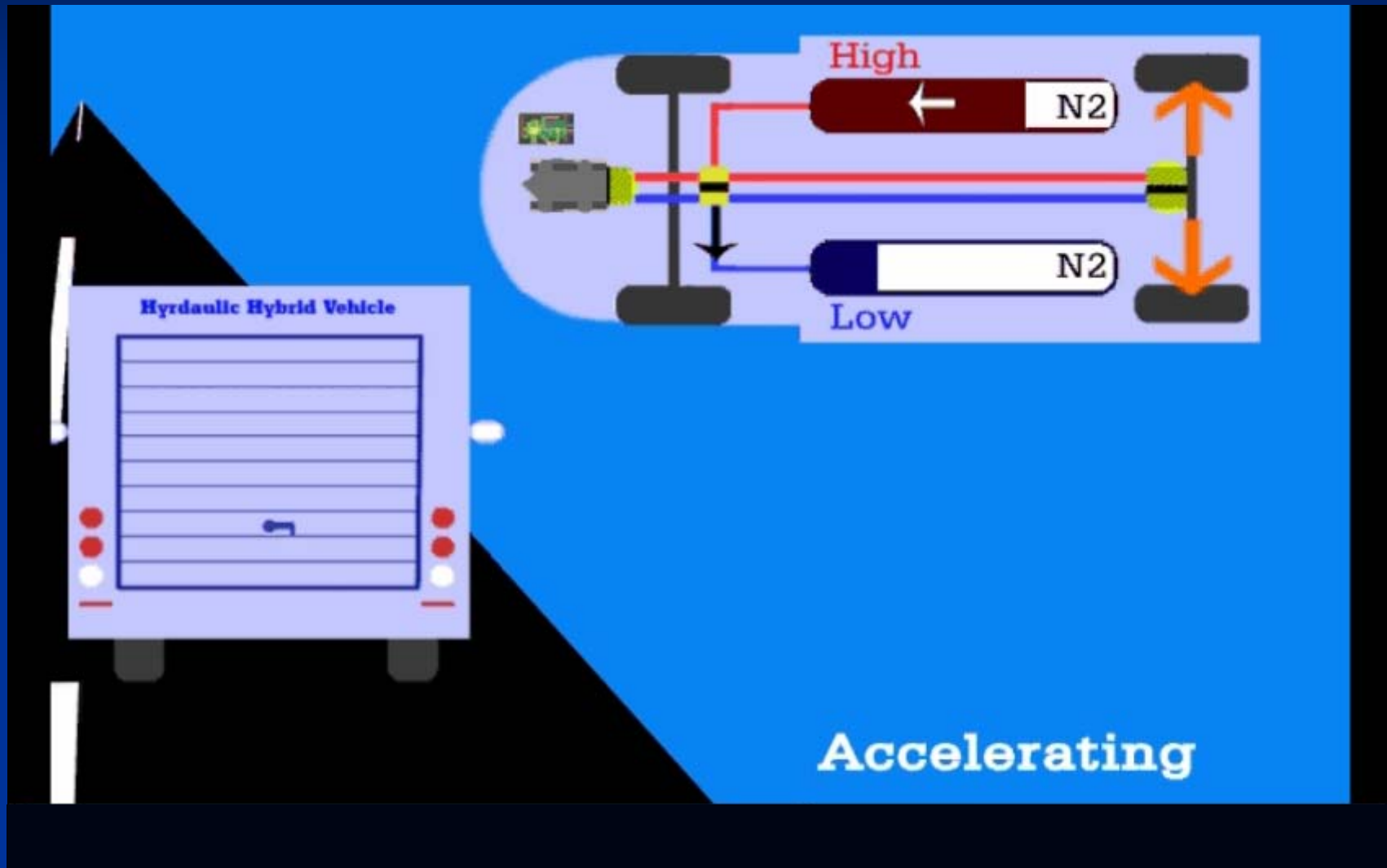


- ✓ At 0 deg - no power produced or absorbed
- ✓ At 45 deg - max power produced or absorbed

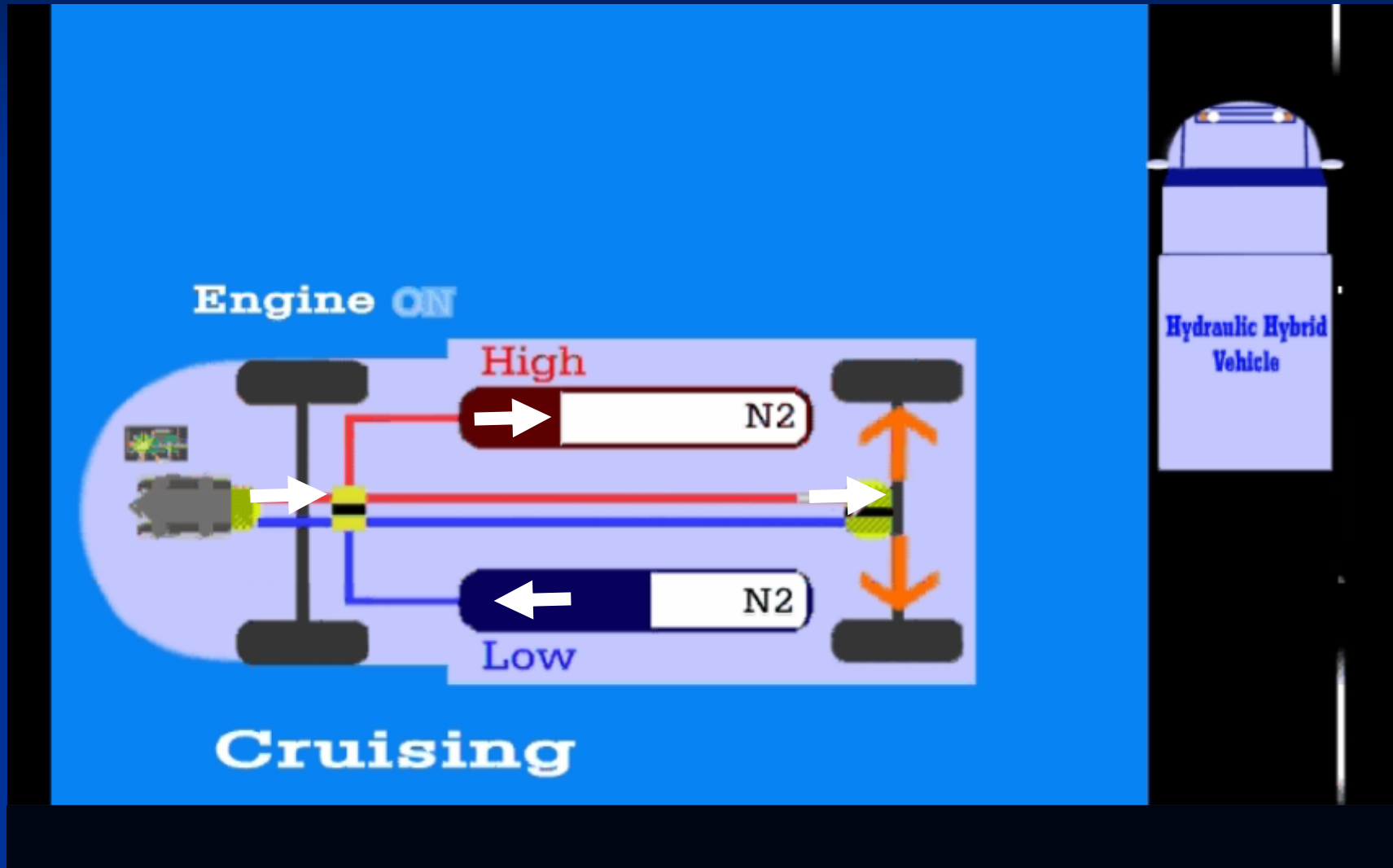
How it Works While Braking



How it Works While Accelerating



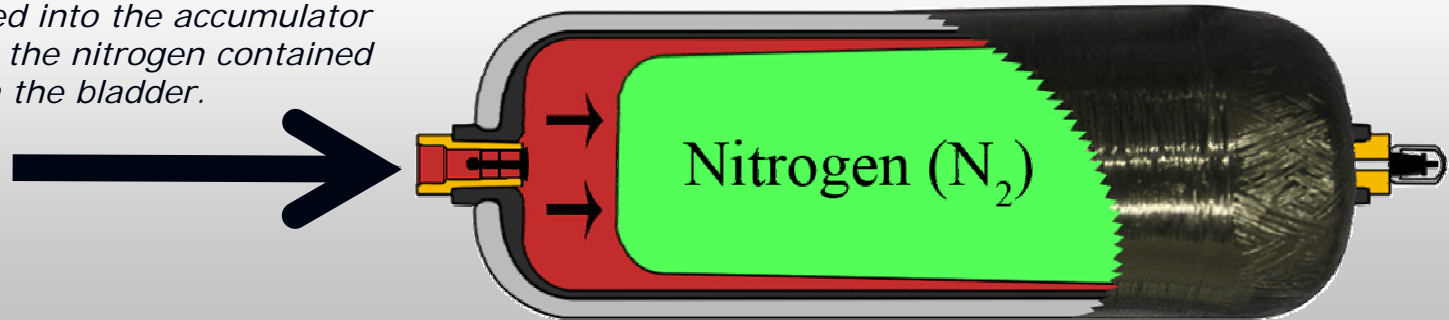
How it Works While Cruising



Types of Accumulators

"Bladder" Style

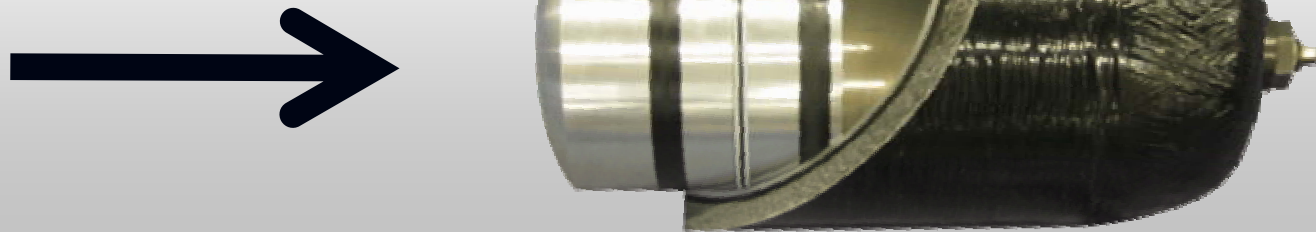
Fluid pumped into the accumulator compresses the nitrogen contained in the bladder.



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*

Yard Hostler Demonstration Project

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

Potential Benefits

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

Partnership Being Formed

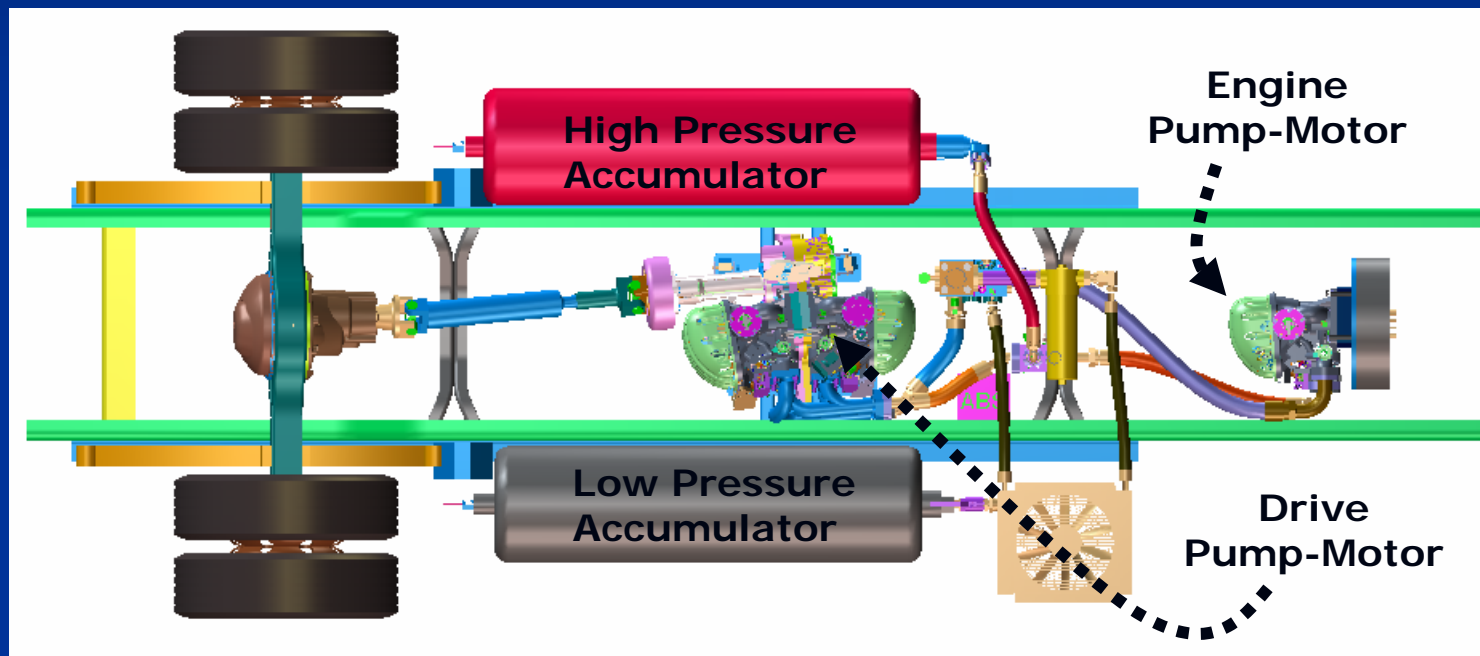
- ✓ EPA (Region 2, OIA, and OTAQ-NVFEL)
- ✓ Port Authority of New York and New Jersey
- ✓ Port of Rotterdam
- ✓ Terminal operator (TBD)
- ✓ Hydraulic hybrid supplier (TBD)
- ✓ Tractor & engine manufacturers (TBD)

EPA's Goals for Series Hydraulic Hybrid Yard Hostler

1. To demonstrate *Best Possible Business Case* for hybrids to both manufacturers / suppliers and to 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

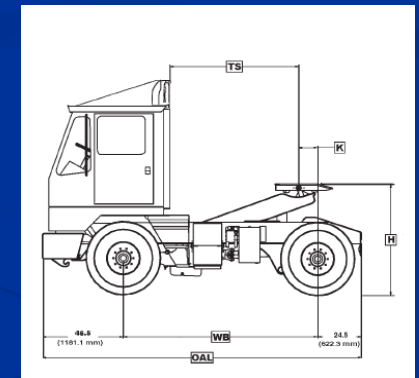


Concept Under Consideration for a Series Hydraulic Hybrid Yard Hostler



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



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>



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