 Diesel Emissions Regulations

Legislation to Reduce:

**Nox – Nitrogen Oxide Gases**
- Combination of gases nitric oxide \((\text{NO})\) and Nitrogen Dioxide \((\text{NO}_2)\).

**DPM – Diesel Particle Matter.**
- Soot, inorganic Oxides primarily sulfates
EPA Emission Regulations
US "Tiers"  Europe "Stages"
Main Emission Reduction Technologies

EGR
Exhaust Gas Recirculation

SCR
Selective Catalytic Reduction

CAC
Charge Air Cooling

DOC/DPF
Diesel Oxidation Catalyst
Diesel Particle Filter
The Customer’s Design Challenge:

More engine power diverted to cooling
(+30% Tier 3 to 4i)
(+10% Tier 4i to 4)

More precise
Engine temperature control

Less space

• Fuel Efficiency
• Space Constraints
• Comfort
• Reliability
Global Fan Drive Market

North America – Fan Drive + Cooler

### Top 10 N.A. Transit Fleets:

<table>
<thead>
<tr>
<th>Transit Fleet</th>
<th>Fleet Size &gt;35Ft</th>
<th>Articulated</th>
<th>Annual Repowers</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTA New York City Transit</td>
<td>3872</td>
<td>621</td>
<td>749</td>
</tr>
<tr>
<td>Metro Los Angeles</td>
<td>2272</td>
<td>388</td>
<td>443</td>
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<tr>
<td>Pace Suburban Bus</td>
<td>422</td>
<td>0</td>
<td>70</td>
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<tr>
<td>New Jersey Transit Corp.</td>
<td>2215</td>
<td>85</td>
<td>383</td>
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<tr>
<td>Toronto Transit</td>
<td>1800</td>
<td>0</td>
<td>300</td>
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<tr>
<td>Chicago Transit Auth</td>
<td>1526</td>
<td>208</td>
<td>289</td>
</tr>
<tr>
<td>Montreal Urban Transit</td>
<td>1572</td>
<td>108</td>
<td>280</td>
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<tr>
<td>Washington Metro</td>
<td>1319</td>
<td>90</td>
<td>235</td>
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<tr>
<td>Southeastern PA Transit</td>
<td>1201</td>
<td>155</td>
<td>226</td>
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<tr>
<td>King County Metro</td>
<td>484</td>
<td>669</td>
<td>192</td>
</tr>
</tbody>
</table>

**Total:**
- Fleet Size >35Ft: 16,685
- Articulated: 2,324
- Annual Repowers: 3,168

**Assumptions:**
- Repower every 6 years covers mix of Transit and Motorcoach buses.

[Diagram showing market share by industry]
Fan Drive Solutions:

**Fixed**
- Direct Engine Drive
- Pulley & Belt Drive

**Variable**
- On/Off Clutch
- Viscous Clutch

**Variable & Remote**
- Electric Motor Drive
- Hydraulic Motor Drive
Why Hydraulic Fan Drives?

3 main reasons...

**Enables emissions reduction...**

- Appropriate Cooling at any engine RPM

**Efficiency....**

- 70-90% Efficient. Frees up Horsepower to do work
- Fuel savings. High Power to Weight Ratio.

**Design advantages...**

- Often utilizes existing hydraulic system
- Reversible - Clear clogged radiators
- Installation Flexibility: Small Size, Locate anywhere
- Fixed tip Clearance = 10-15% more cooling efficiency
Hydraulic Solutions & Components

ENGINEERING YOUR SUCCESS.
Fan Drive Power

2X Fan Speed Requires 8X Hydraulic Power
Fan Drive: ‘Bleed-Off’ Variable Fan Speed

- Hydraulic Motor
- Pressure Relief
- Optional Reversing Valve
- Anti-Cavitation motor check
- Dry-Motor protection Anti-starve check

Graph: Engine Speed vs Fan Speed

- Engine Speed (RPM)
- Fan Speed (RPM)
- Engine Speed vs Fan Speed

- Fan Speed now variable, (Proportional Relief Command)
# Gear Solutions: Fan Pumps & Motors

## Table of Cast Iron and Aluminum Products

<table>
<thead>
<tr>
<th>Displ</th>
<th>CAST IRON</th>
<th>ALUMINUM</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>PGP/M 300</td>
<td>PGP/M 600</td>
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<tr>
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</tr>
<tr>
<td>10</td>
<td>315</td>
<td></td>
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<tr>
<td>20</td>
<td>330</td>
<td>610</td>
</tr>
<tr>
<td>30</td>
<td>350</td>
<td>620</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>150</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Mature Product**
- **Core Fan Drive Product**
- **S** Spilt Gear Available

**Up to 4000 psi (270 Bar)**
Cast Iron Preferred for Fan Drives:
Aluminum vs Parker 600 Iron Series Efficiency
600 Series Pump & Motor

Patented 2 Piece Interlocking Body

- Stiffer Assembly
  - Higher Pressures
  - Higher Volumetric & Efficiency
- Compact Size
  - Lower Weight
  - Easier Installation
- Thermally Stable
  Proven at Extreme Temps

2-piece

Channel seals

Pressure balanced wear plates

Section seal

Shaft seal
New Integrated PGM620 Fan Motor

- Purpose build integrated design for lower cost and smaller package
Vane Motor Solutions
“Designed For ” Fan Drives

- Unique protected shaft seal, barrier to blown in debris
- Heavy duty, long life bearings to support fan loads
- Very low noise

- Excellent mechanical efficiency from hydrostatically balanced rotor
- Double lip vanes resist contamination and maintain efficiency vs pressure and time

Hydrostatically balanced rotor
Double lip vanes
M5 A, B and ASF
All-In-One
Integrated Fan Motor

• Proportional Relief
• Reversing Valve
• Anti Cavitation Check
• Anti-Drain Valve
• Speed Sensor

...Or various combinations
Fan Drive:
Variable Piston Pump, Integral Proportional Pressure Control

System Pump

Hydraulic Motor

P1 Proportional Pressure Control

Optional Reversing Valve

Pressure Command
Piston Pump Solutions

Bus Market:
• OEMs drove Gear/Gear solutions
• Transit Authorities demanded electric solutions

Fuel Savings

Gear/Gear Hydraulic Drive $

Piston Solutions

Electric Drive $$$

Piston Solutions

P1 Pump
Proportional Pressure Control

P1 Pump
Electronic Displacement Control
Bent Axis Pumps & Motors

- Unbeatable Power Density & Efficiency
- High Fan Speed – High air flow from small fans
- Speed sensor port for closed loop control
- Heavy duty bearings - direct fan mounting, axial & radial loads
- Wide Temperature Range (-40°C to +115°C)

95% Total efficiency
(volumetric + mechanical over wide range)
Parker Coolers

- Rugged Bar and Plate Coolers
- Combi Coolers
- Radiator, CAC, Oil
- Global: NA, Europe, China
Full Cooling System Design Support
HCS/HCSE Manifolds

- Multiple Fan Drive Circuits:
  - Stand Alone Fan Control
  - Or combine with Steering, Braking, etc

- Extensive Fan Drive Experience

- Wide Product Range
Fan Drive Reservoir & Integrated Filter

- Rugged cylindrical cold rolled steel
  - Rugged & Space efficient
- Aftermarket protected filter (patented element)
- Integral breather keeps dirt out
- Microglass media for cleaner fluid and extended service life
- Visual level and filter site gages
- Easy top service element replacement
- Multiple port options for power steering & case drain

Bulletin 2300-455-1
Fan Drive and System Controllers

- Parker Interfaces with Engine Controller
- Vehicle Controller Management
Pump & Motor Combinations optimize performance and value

<table>
<thead>
<tr>
<th>Pump</th>
<th>Motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piston</td>
<td>Piston</td>
</tr>
<tr>
<td>Vane</td>
<td>Vane</td>
</tr>
<tr>
<td>Gear</td>
<td>Gear</td>
</tr>
</tbody>
</table>

Fan Motor Comparison

- motor efficiency
- fan bearings
- power to size
- valve integration
- power to weight
- fluid temperature
- pressure
- speed
- noise
- price

- **bent-axis piston fixed displacement**
- **vane fixed displacement**
- **gear fixed displacement**
Electric Fan Drive Solutions
GMS - EM Fan Drive System Development

Needs:
- Fuel Savings
- Reduced Fire Hazard
- Reduced Noise
- Green initiative

Solution
- Parker Electric Fan Drive System
- Low voltage system for Transit Authorities, Bus Refurbishers / Repower facilities

Success Factors
- Able to be a full solution provider.
- System solution from ECD’s MC2 controller, to Parker’s low voltage inverters and motors

Customer Value
- Improved fuel economy
- Reduction in parasitic losses
- Reduction in noise
- Reduction in fire hazards

Lead Sales Contact
Patrick Berkner Global Mobile Systems

Featured Products:
- Parker Electric Fan Drive System
- AUG motors and controllers

Market:
- Bus & Coach, Construction

Distributor:
- Direct
GMS - EM Fan Drive System Development

Block Diagram

- Diesel Engine
- Alternator
- 24 Vdc Bus Bar
- 3 phase PWM
- CAN
GMS - EM Fan Drive System Development

This Fan System is still in Development

- Target customer is the Transit Authority, bus refurbisher, repower facility
  - NOT OEM’s
  - TA’s look for Fuel savings, reduction in maintenance, etc.

- Now with Parker Olaer as a solution, Parker can be able to provide a full solution

- Olaer oil coolers
  - In the short term – they can supply oil coolers to the truck markets.
    - Can be used for smaller radiators for hybrid trucks, smaller vehicles.

- If you believe you have a potential opportunity, talk to Pat Berkner to discuss.
# Sizing & Specification

## Fan Motor Input Information

<table>
<thead>
<tr>
<th>Fan Motor RPM</th>
<th>Input Torque (nm)</th>
<th>Required Fan Motor Power (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>10.4</td>
<td>0.5</td>
</tr>
<tr>
<td>1000</td>
<td>41.4</td>
<td>4.3</td>
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<tr>
<td>1500</td>
<td>93.3</td>
<td>14.6</td>
</tr>
<tr>
<td>1700</td>
<td>119.8</td>
<td>21.3</td>
</tr>
</tbody>
</table>

---

**Parker**

*Engineering Your Success.*
Questions To Ask…

Pump and Motor Sizing Questions:
- Maximum fan speed needed?
- Lowest pump rpm need to achieve the maximum fan speed?
- Rated power of the fan at its rated speed?
- Maximum power or torque available to drive the pump?
- Minimum and maximum engine speed?
- Maximum allowable or desired hydraulic pressure?

Other Clarifying Questions:
- Thrust, axial and dynamic loads on the fan motor?
- What features are needed {reversing, speed control, etc}?
- Duty cycle of the fan?
- Mounting, shaft and porting on the pump and motor?
- Space restrictions?
Additional Factors:

To Accurately Calculate the Fan / Hydraulic Performance it is very important to:-

1. Account for Pump & Motor Efficiencies over the speed and temperature range.
2. Consider total hydraulic losses (hoses, valves…).
3. Address Dynamic Forces on the motor:
Sizing Programs Available

![Image of software interface showing calculations for fixed pump and fixed motor, including power, speed, system parameters, and output values such as pump displacement, motor displacement, fan power, torque, and flow rate.]
Typical Bus Circuit:
Single Fan, Torque Limiting Option, Excess Flow To Tank

Typical On-Road Circuits
- School Bus
- Transit Authority
- Airport Shuttle Bus
Total System Solution – Bus OEM

- Parker Fan Drive System for all Tier III rear engine applications
  - Total System Performance was driving factor
  - Customer impressed with GPD & FCG service levels for prototypes and rapid system development
Keys to the Win

• Focused Team (TBB unfamiliar with hydraulics)
• 600 Performance
• System Approach
• Won with **Performance**, Maintained with **Support**

Lessons Learned

• High Temps: Controller, Pump/Motor
• System Cleanliness
• Validate to Entire Cooling Duty Cycle
• Bus Market: No BS, Field Support
Sales Strategy & Support

ENGINEERING YOUR SUCCESS.
Cooling System Integration is very Complex:

An optimized cooling system requires skilled integration of multiple technologies.

- **Hydraulic Fan Drive**
  - Hydraulic System Type
  - System Efficiency
  - Durability
  - Motor Bearing Load
  - Valve & Control Options
  - Noise
  - Space

- **Cooler**
  - Space
  - Cooler Type
  - Cooling Capacity
  - Cooling Fluid Flow
  - Air Characteristics
  - Air Recirculation
  - Safety Factors

- **Vehicle**
  - Engine Cooling Spec
  - Engine Audit Tests
  - Drivability
  - Vehicle Performance
  - Altitude & Environment
  - Space
  - Control & Sensors

- **Fan**
  - Power Curve
  - Max Torque
  - Airflow vs. Speed
  - Noise
  - Thrust & Axial Loads
  - Efficiency

- **Engine**
  - Cooling Load Specs
  - Audit Requirements
  - Coolant Flow
  - Fan Drive Torque Limits
System Integration & Supply

= FD System Integrator  ⇐ = Value & Supply

Engine OEM

Hydraulic Supplier

Hydraulic Distributor

Cooler Supplier

Fan Supplier

Engine Dealer

3rd Party Integrator

Bus Rebuilder

Truck OEM  Chassis OEM  Military Prime  Off Road OEM  Bus OEM  City Transit Authority

End Customer
Parker Capability
Full Cooling System Integration

- Full Cooling System
  - Optimized Design
    - Full Cooling System
      - Fan Drive, Cooler, Fan
  - Kit or Assembly
    - Full Cooling System
      - Fan Drive, Cooler, Fan
- Design Value
- Fan Drive System Design
  - Component Specifications
- Supply Chain Value
- Kit - Fan Drive System
  - Component Supply
Electrical Controllers - Fan Drive & Full System

With overall vehicle electronic control systems becoming more common in the bus market, the ability to integrate the fan drive control logic into the rest of the vehicle control system is important. Parker Hannifin offers a wide variety of CAN bus-based control platforms that can be integrated with the fan drive hydraulics. Integrating the fan drive into the overall vehicle control system can reduce the installation time and cost, reduce diagnostic time and increase fan drive efficiency by allowing all the vehicle functions that could affect fan drive performance to be monitored. Integrating the fan drive into the vehicle control system still allows for full fan drive functionality, including:

- BAE J1939 CAN and analog inputs for fan speed control
- Fan reversing with ramps
- Automated and manual fan reversing
- Multiple fan locations with independent control
- Improved fault detection and diagnostics
- Software configuration of parameters

Basic hydraulic solutions for the fan drive

for the bus market