# Fan Drives in Mobile Hydraulic Applications

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MEMBER OF THE SAUER-DANFOSS GROUP

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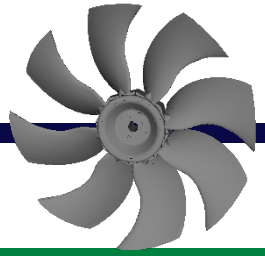
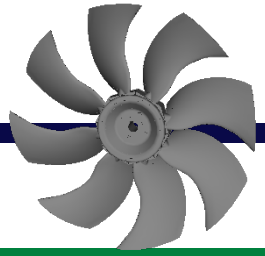
# Fan Drives in Mobile Hydraulic Applications



- Introduction
- Cooling System Overview
- Power Sources
- Heat Sources
- Cooling Sources
- Fan Operation
- Fan Drive Systems Overview
- Hydraulic Fan Drive Systems and Capabilities
- Advanced Hydraulic Systems



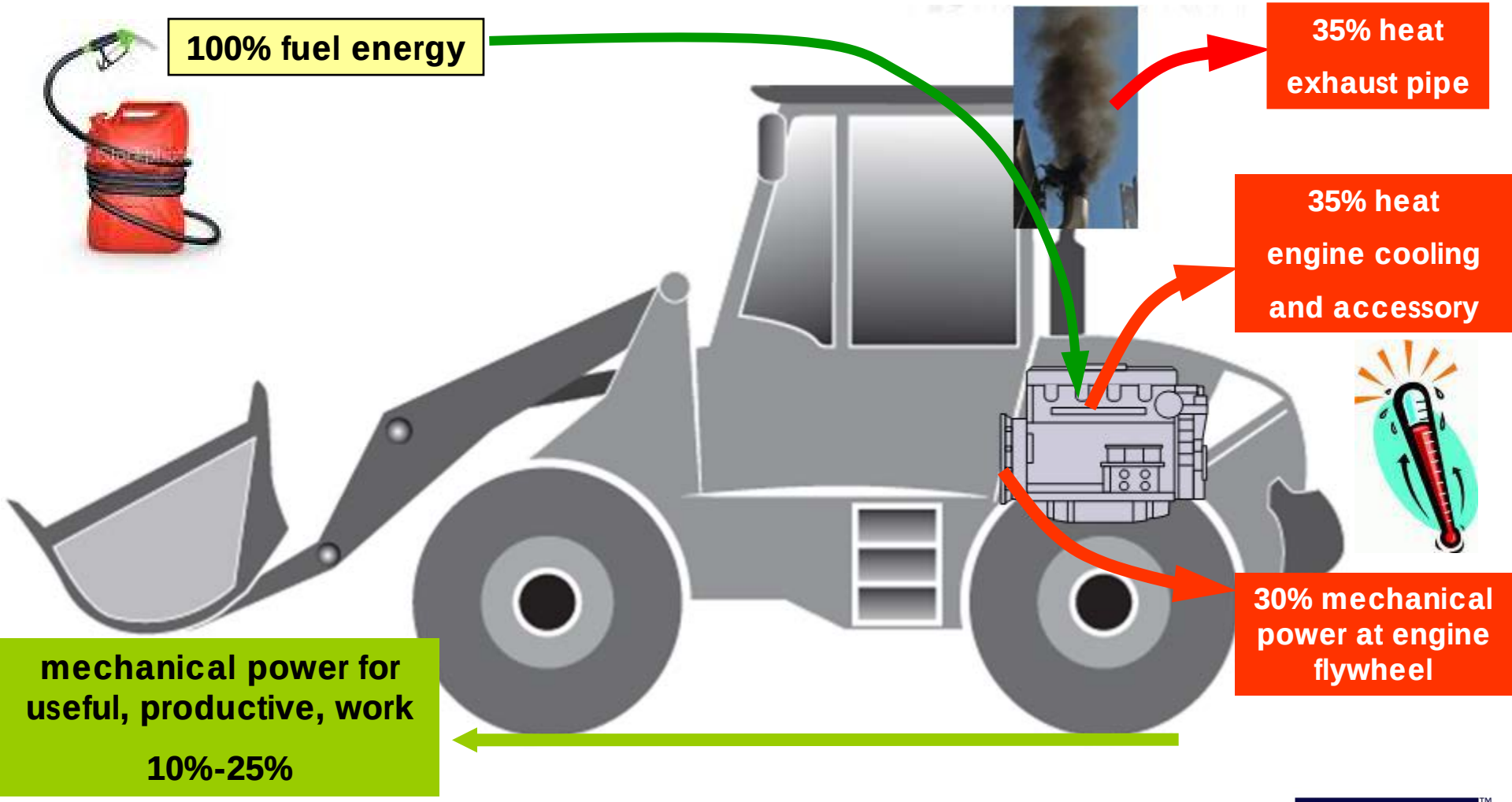
## Introduction

# Why would I want to use a fan in my mobile machine?

- Operator Climate Control
  - Heating, cooling, filtering, positive pressure cabs
- Useful machine work
  - Venting, Drying, Cleaning
- Removing Waste Heat

# Fan Drives in Mobile Hydraulic Applications

## Why do we need fan drives for cooling?



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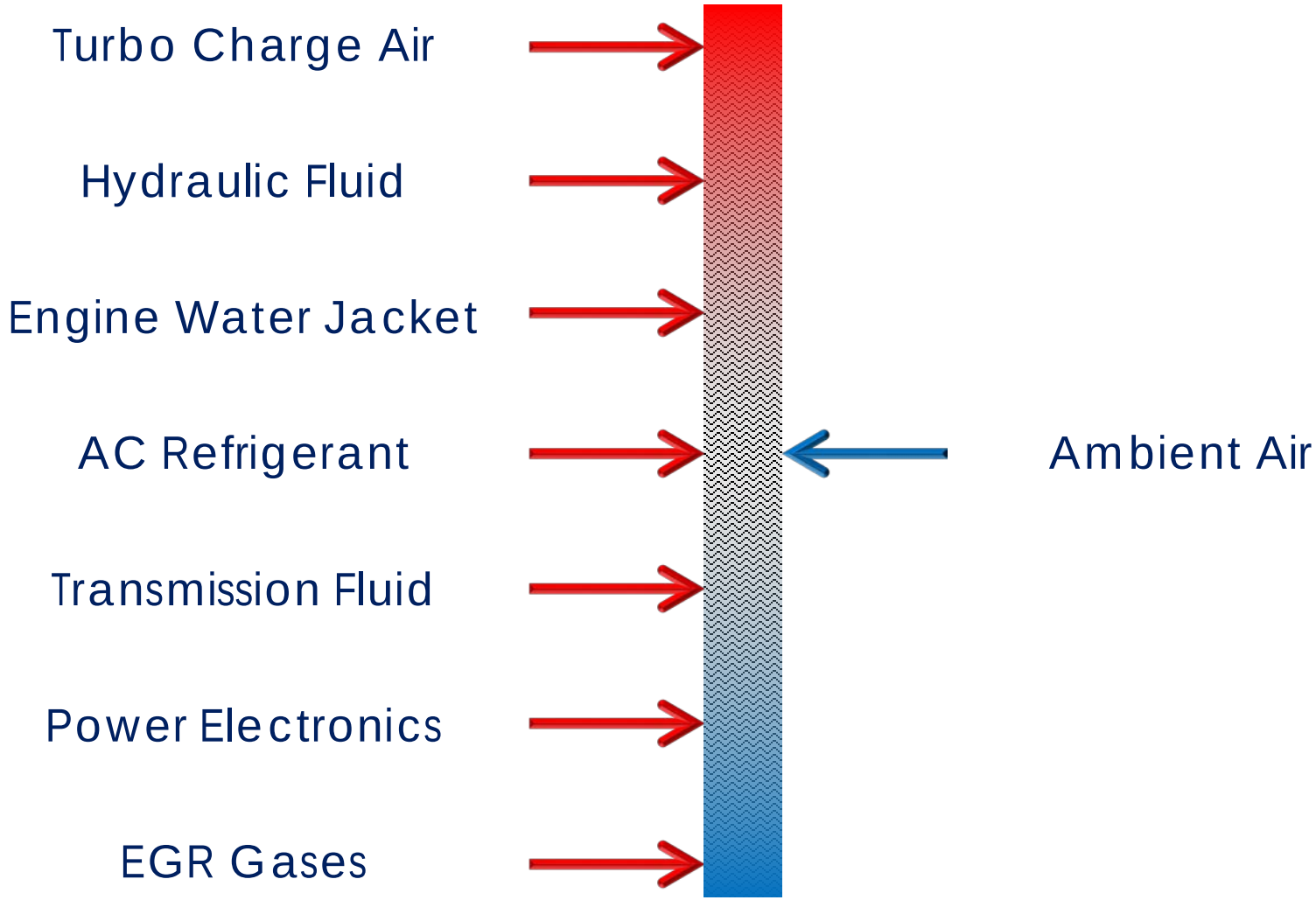
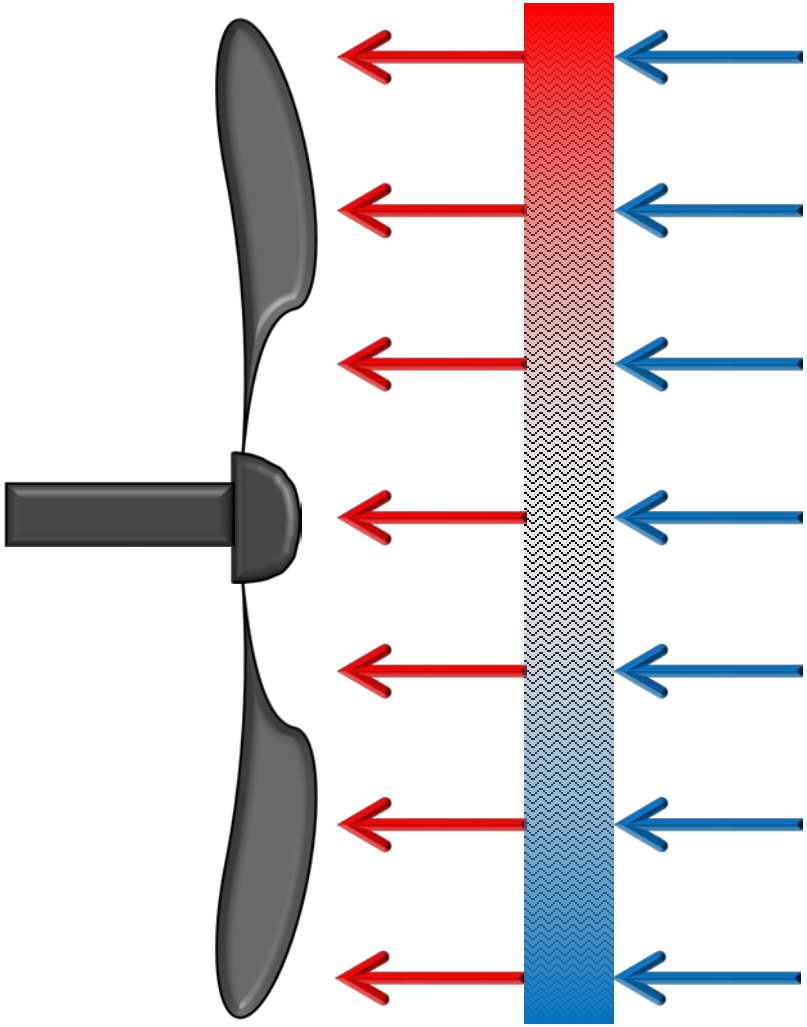
# Fan Drives in Mobile Hydraulic Applications

## Introduction

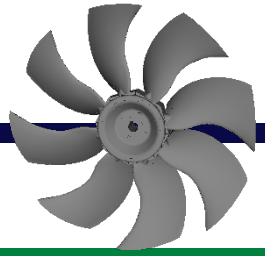


# Fan Operation

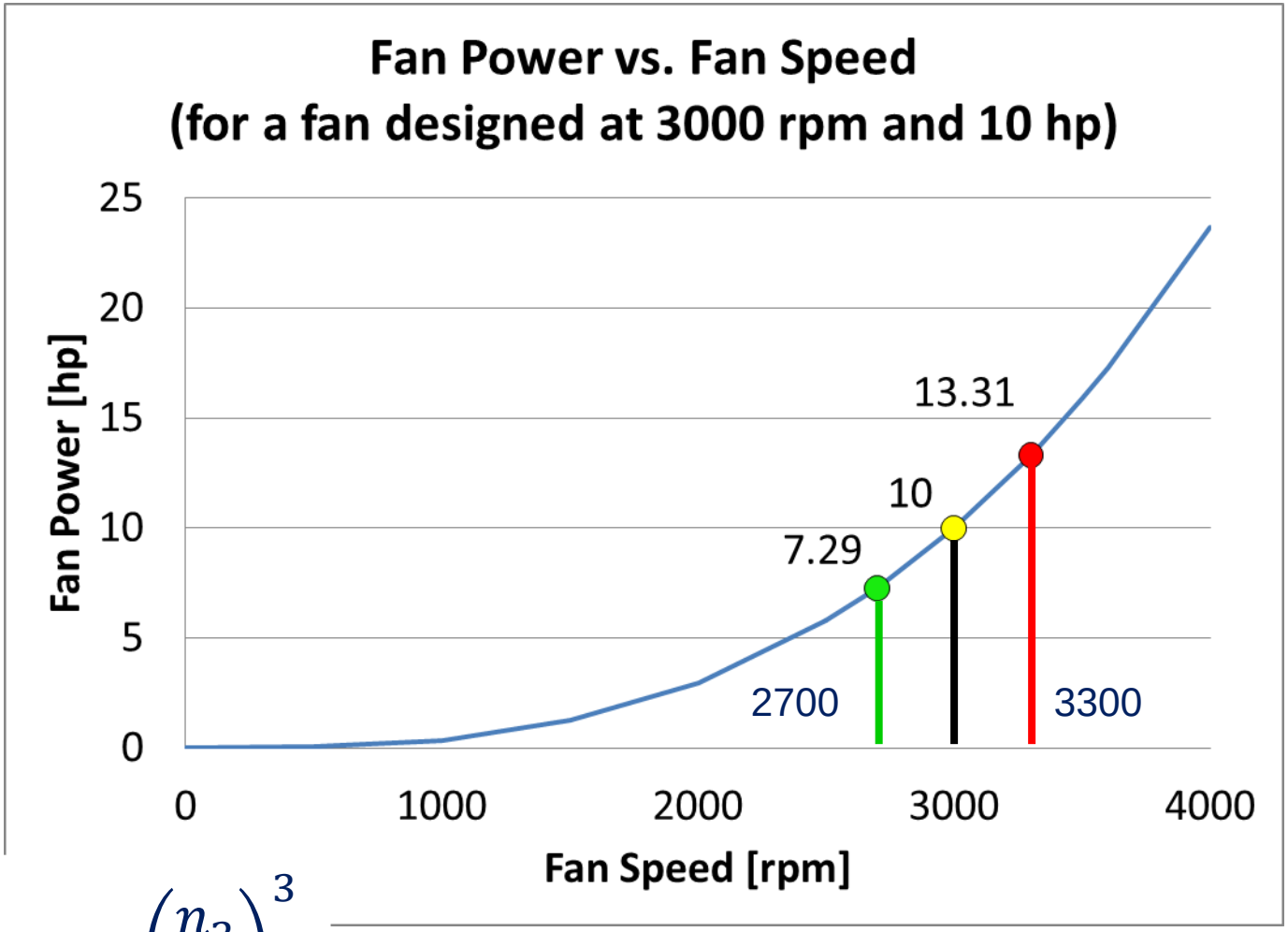


$$T_2 = T_1 * k * \left(\frac{n_2}{n_1}\right)^2$$

$$P_2 = P_1 * k * \left(\frac{n_2}{n_1}\right)^3$$



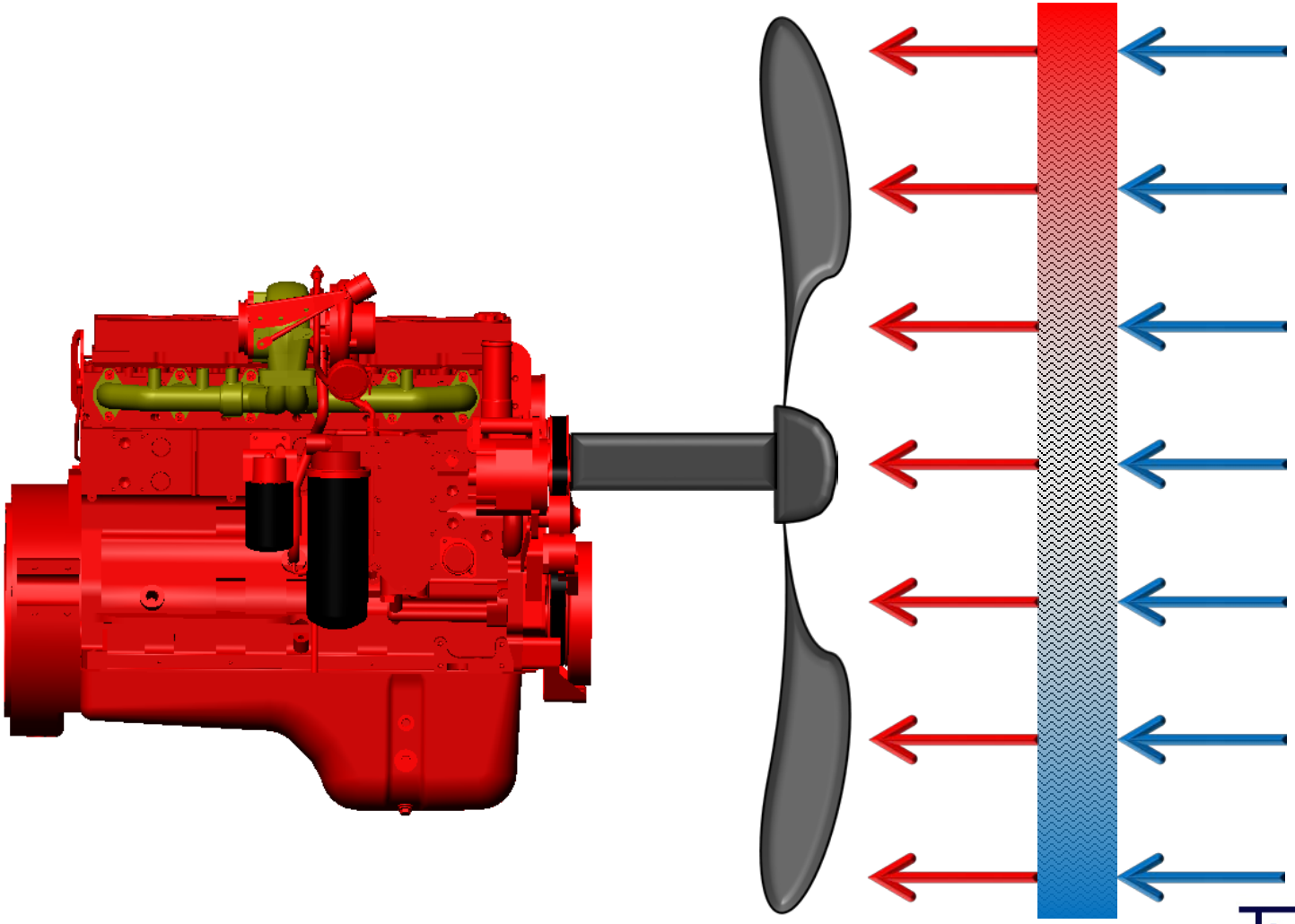
# Fan Operation

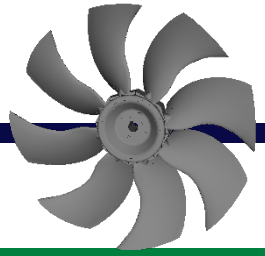



$$P_2 = P_1 * k * \left(\frac{n_2}{n_1}\right)^3$$

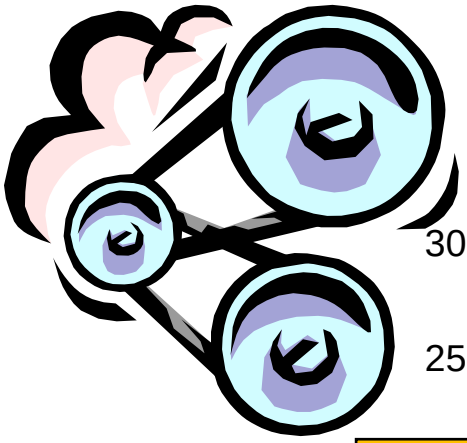
# Fan Drives in Mobile Hydraulic Applications

## Fixed Ratio Mechanical Fan Drive Operation



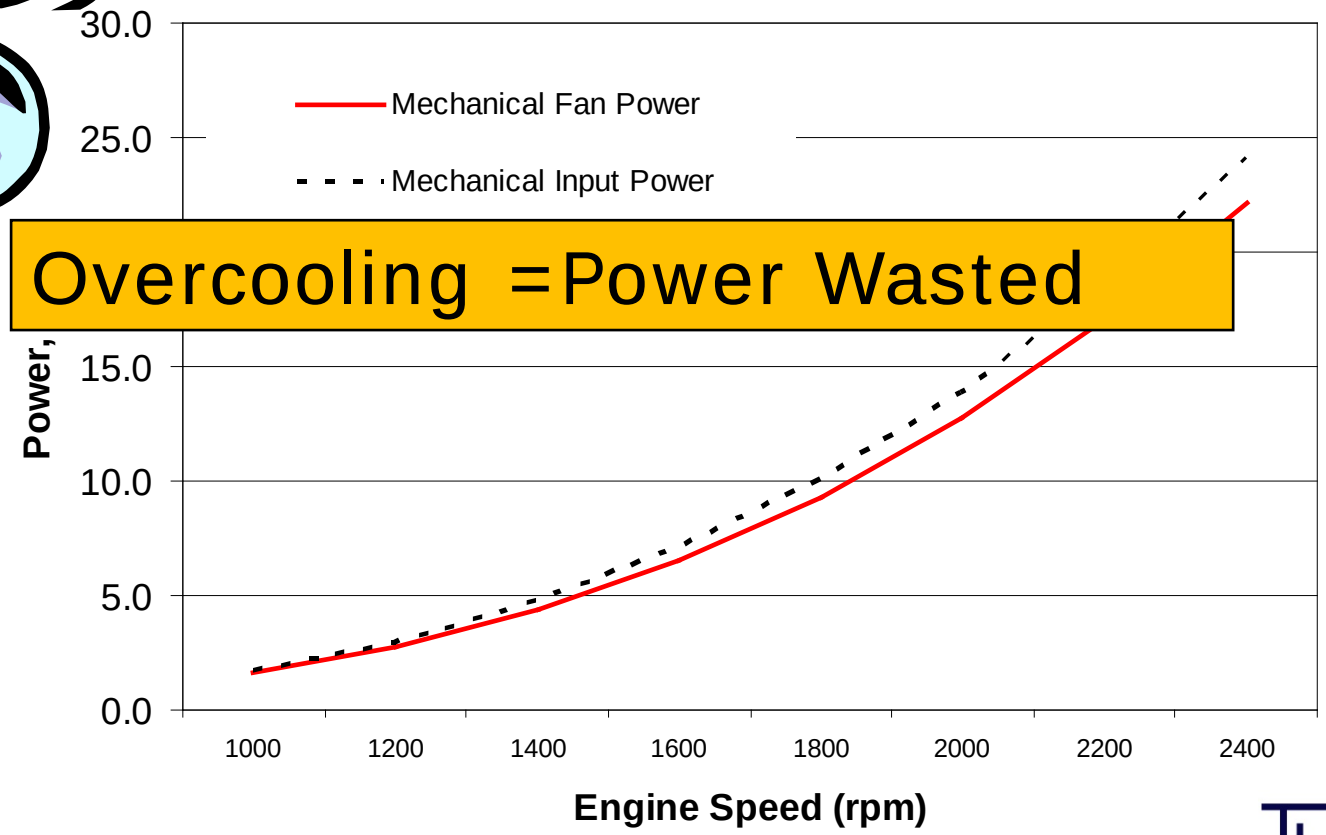


# Fan Power vs. Fan Speed



## Belts are efficient, why change?

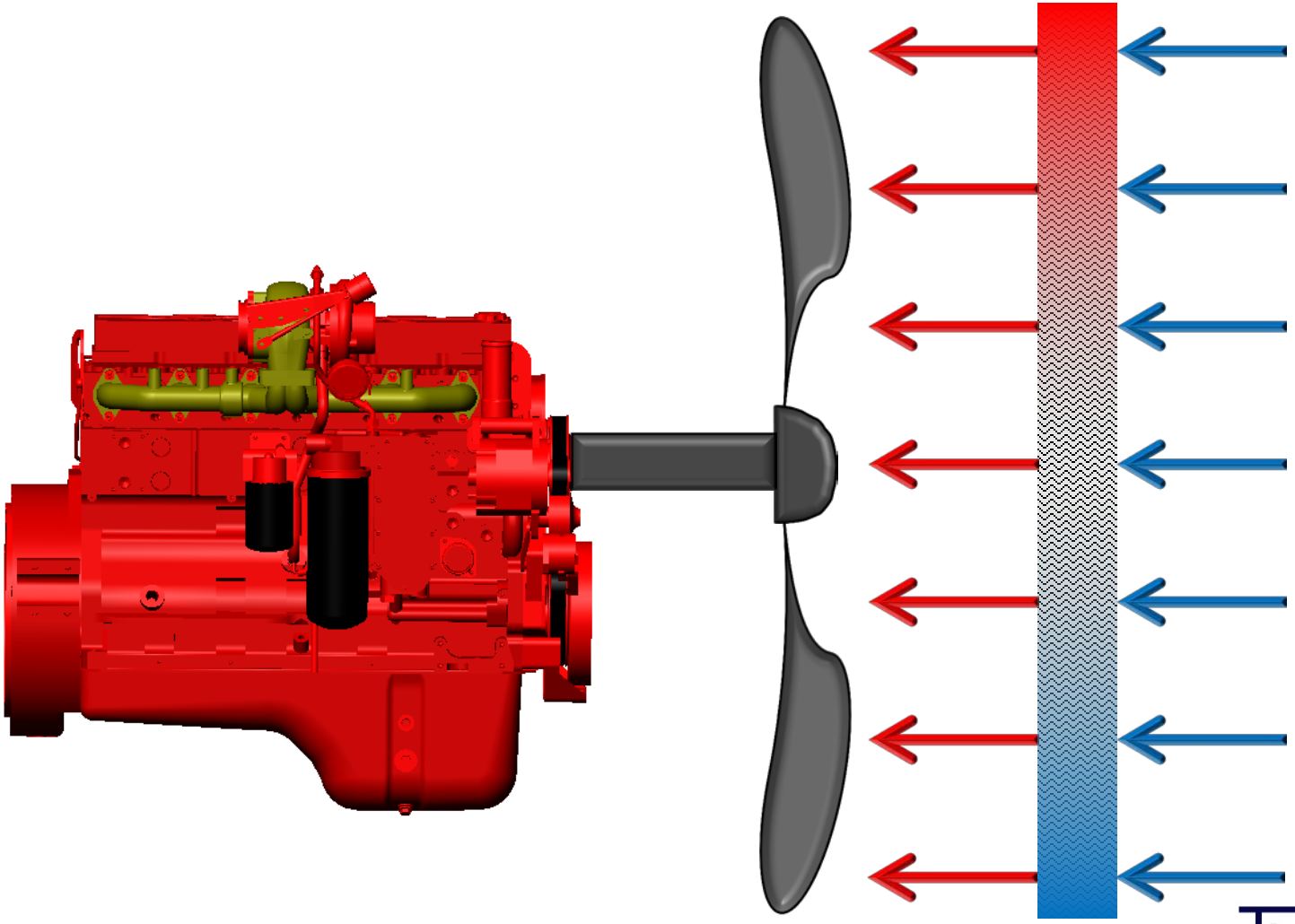
Fan Power Law = K x (engine speed)$^3$




**Overcooling = Power Wasted**

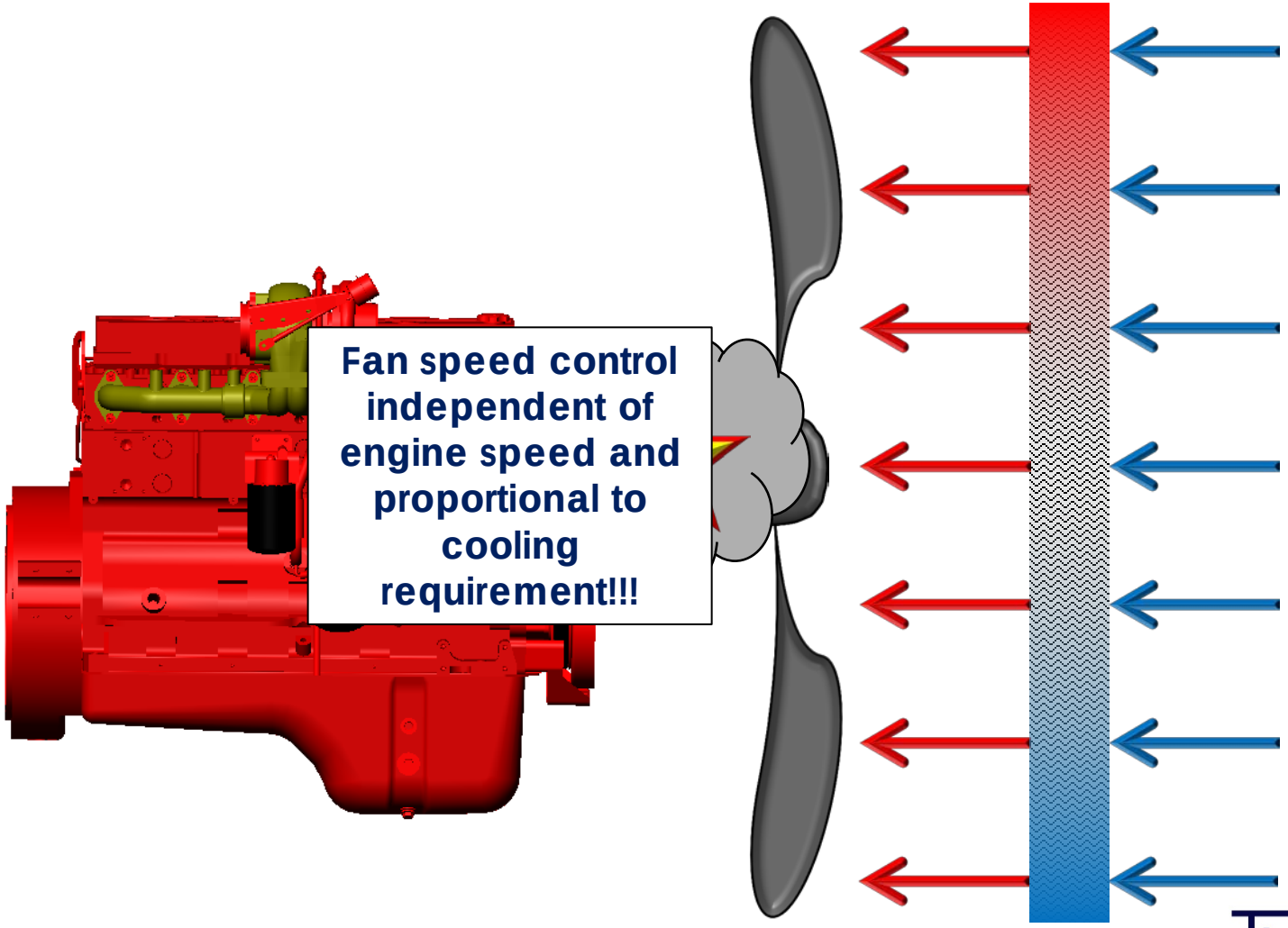
# Fan Drives in Mobile Hydraulic Applications

## Fixed Ratio Mechanical Fan Drive Operation



# Fan Drives in Mobile Hydraulic Applications

## Break free from the fixed ratio!



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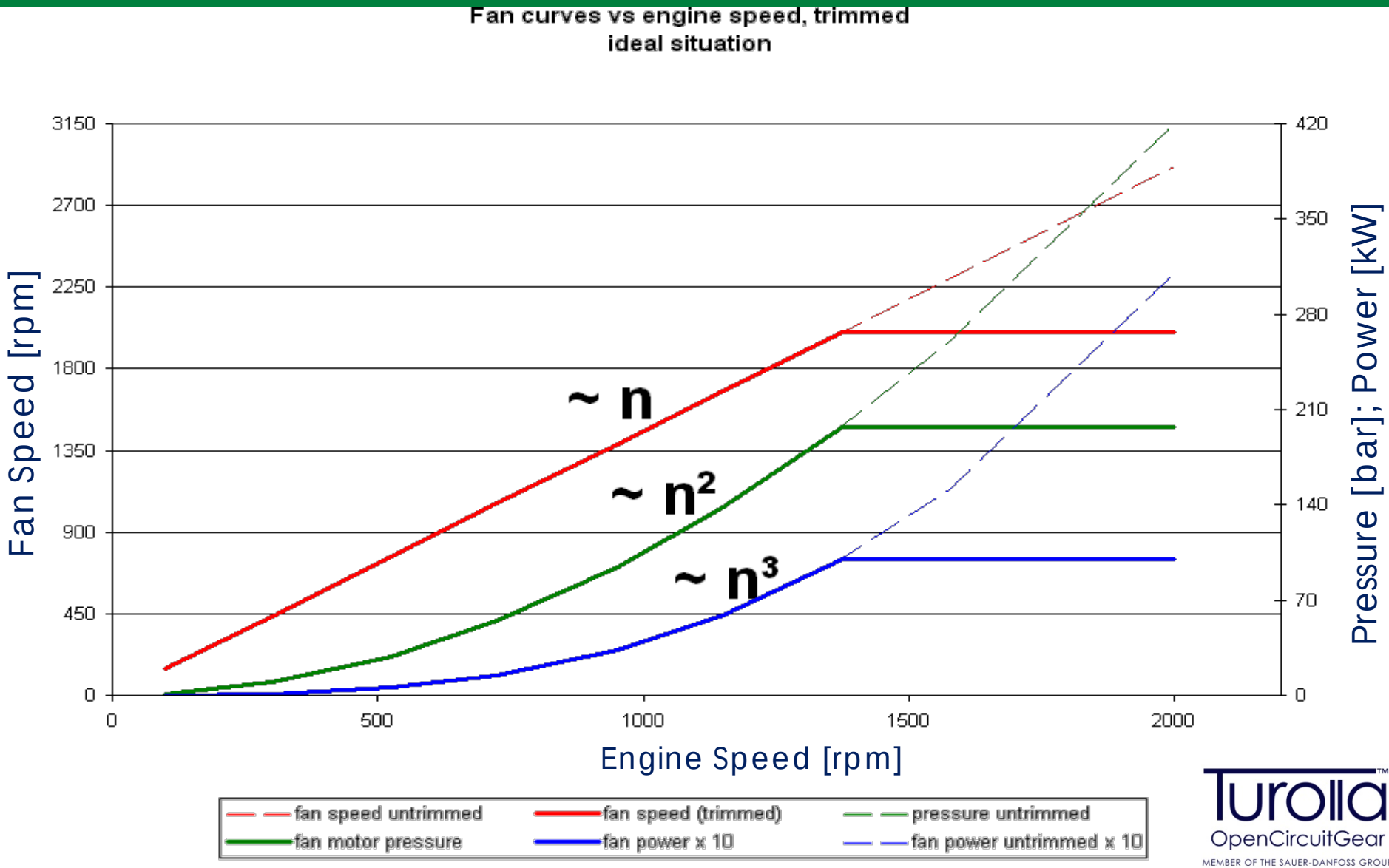
# Fan Drives in Mobile Hydraulic Applications

## Fan Operation vs. Engine Speed

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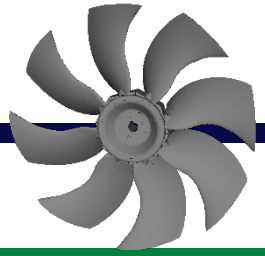


# So what if I save power on this fan drive system?

- Fan system is not producing useful work (parasitic loss)
- Saving power on cooling leaves more power for useful work
- Saving power on cooling saves fuel and reduces operating cost

# Fan Drives in Mobile Hydraulic Applications

## Power and Energy Savings

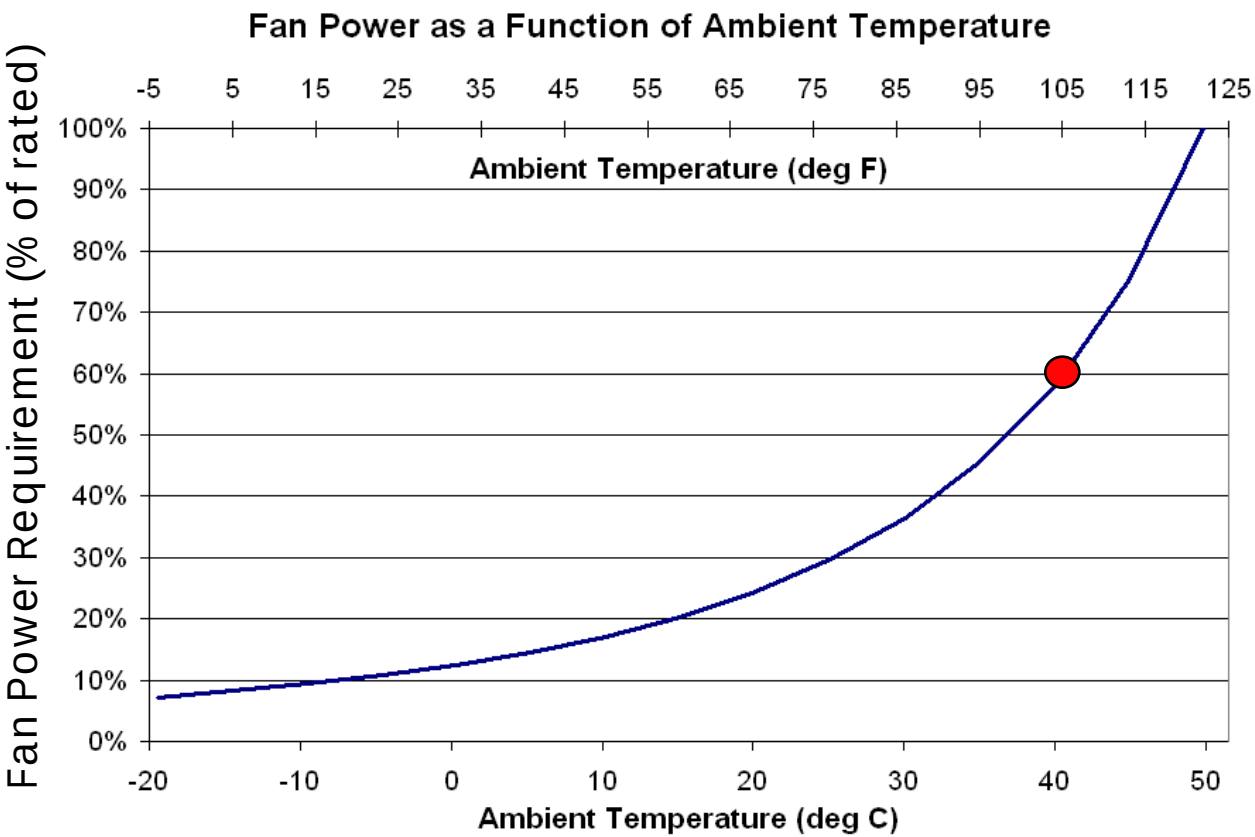
- 200 hp machine
- 30 hp fan (15% of Engine Power)
- Fuel Cost: $3.50/gal
- Specific fuel consumption .3518 lb./hp-hr
- 7.3 lb/gal of diesel fuel
- Operating days/year: 180 days/year
- Operating hours/day: 8 hours/day
- 10% decrease in average fan speed (33.1% power savings)
- 9.93 hp saved on average

$$\frac{.3518 \cdot lb}{hp \cdot hr} * \frac{9.93 \cdot hp}{1} * \frac{8 \cdot hr}{day} * \frac{180 \cdot day}{year} * \frac{gal}{7.3 \cdot lb} * \frac{\$3.50}{gal} = \$2412 / yr$$

# Fan Drives in Mobile Hydraulic Applications

## Fan Power as a Function of Temperature

$$\frac{T_{Coolant} - T_{ActualAmb}}{T_{Coolant} - T_{MaxAmbient}} = Cooling\_Effectiveness \qquad P_{Fan} = \frac{P_{Fan\_\max}}{(Cooling\_Effectiveness)^3}$$




@ Vehicle Maximum Heat Rejection

105°F (42°C) takes 60% of Full Power



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# Fan Drives in Mobile Hydraulic Applications

## Fan Noise vs. Fan Speed

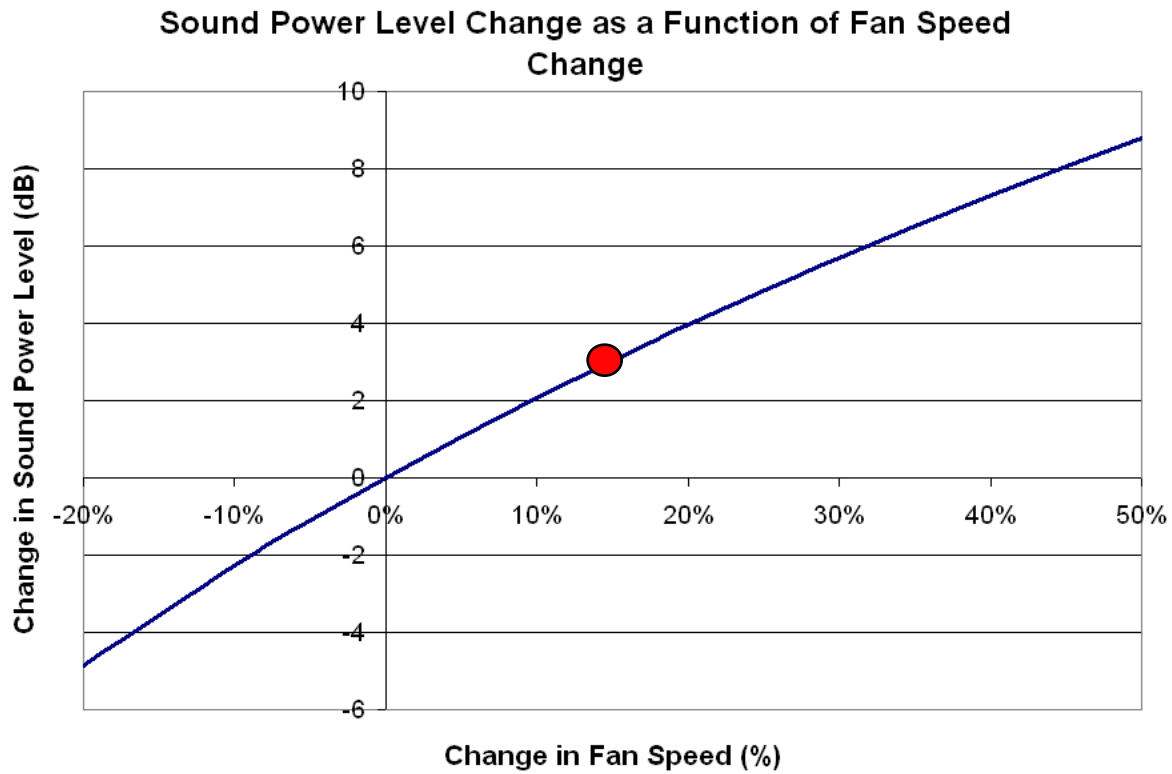
$$Lw_c = Lw_b + (50)\log_{10}\left(\frac{N_c}{N_b}\right)$$

15% Increase in Fan Speed

$$Lw_c = Lw_b + (50)\log_{10}\left(\frac{1.15}{1}\right)$$

$$Lw_c = Lw_b + 3dB$$

**3dB Increase in Fan Noise doubles the noise level to the human ear**




**European Noise Legislation:**

DIRECTIVE 2000/14/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 8 May 2000

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# Noise Legislation

**DIRECTIVE 2005/88/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL**

**of 14 December 2005**

**amending Directive 2000/14/EC on the approximation of the laws of the Member States relating to the noise emission in the environment by equipment for use outdoors**

(c) Fan drive with continuous variable speed

If the fan can work at continuous variable speed, the test shall be carried out either according to 2.1(b) or with the fan speed set by the manufacturer at no less than 70 % of the maximum speed.

# Noise Legislation

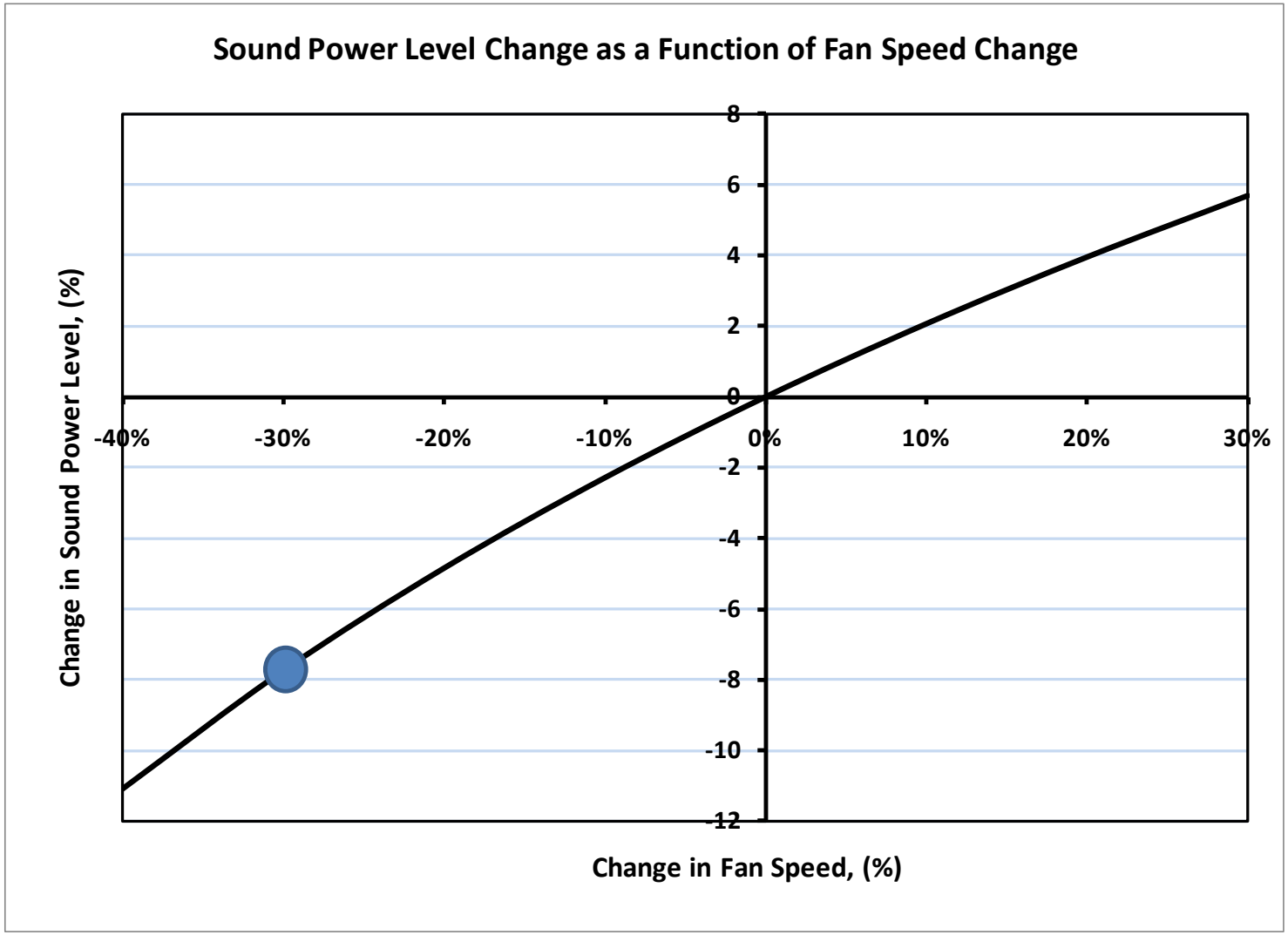
## OSHA Noise Exposure Limits:

| Sound Level (dBA) | Exposure Limit (hours/day) |
|---|---|
| 90 | 8 |
| 92 | 6 |
| 95 | 4 |
| 97 | 3 |
| 100 | 2 |

* Employee notifications are required for environments with sound levels greater than 85 dBA

# Fan Drives in Mobile Hydraulic Applications

## Noise Legislation



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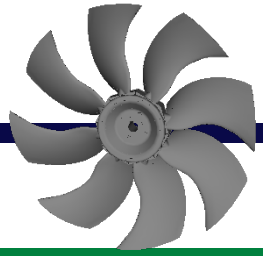
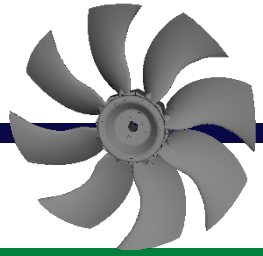
# Fan Drives in Mobile Hydraulic Applications



## Proportional Fan Drive Types

- Mechanical Continuously Variable Transmissions
- Viscous Clutch Drives
- Electric Generator/Motor Drives
- Variable Pitch Fan Blades
- **Hydraulic Fan Drive Systems**

# Fan Drives in Mobile Hydraulic Applications

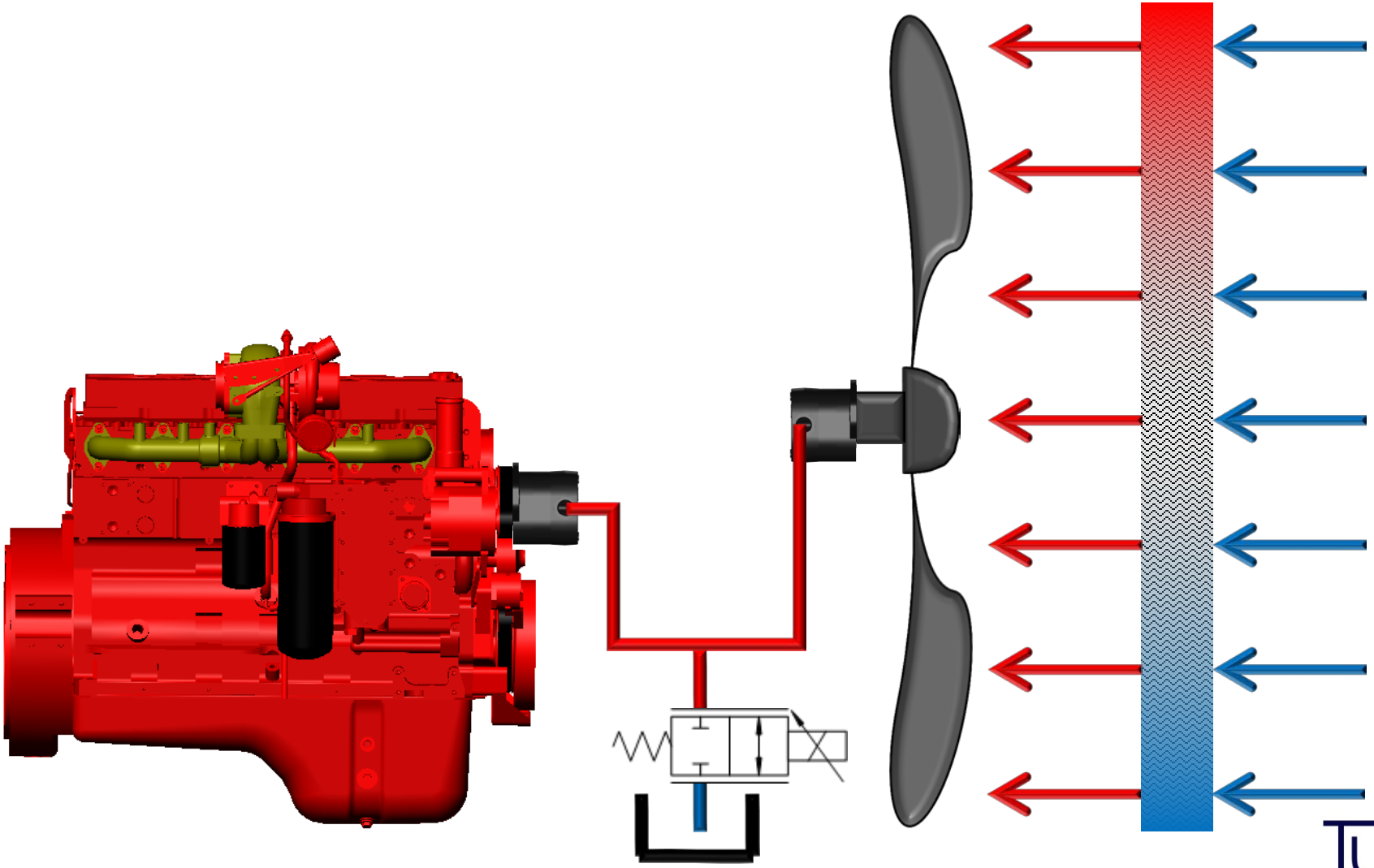


## Hydraulic System Advantages

- Compliments other hydraulic machine functions
  - Propel
  - Work function
- Flexible connections allow for optimal cooler location
- Reversing is an option
- Fan off function

# Fan Drives in Mobile Hydraulic Applications

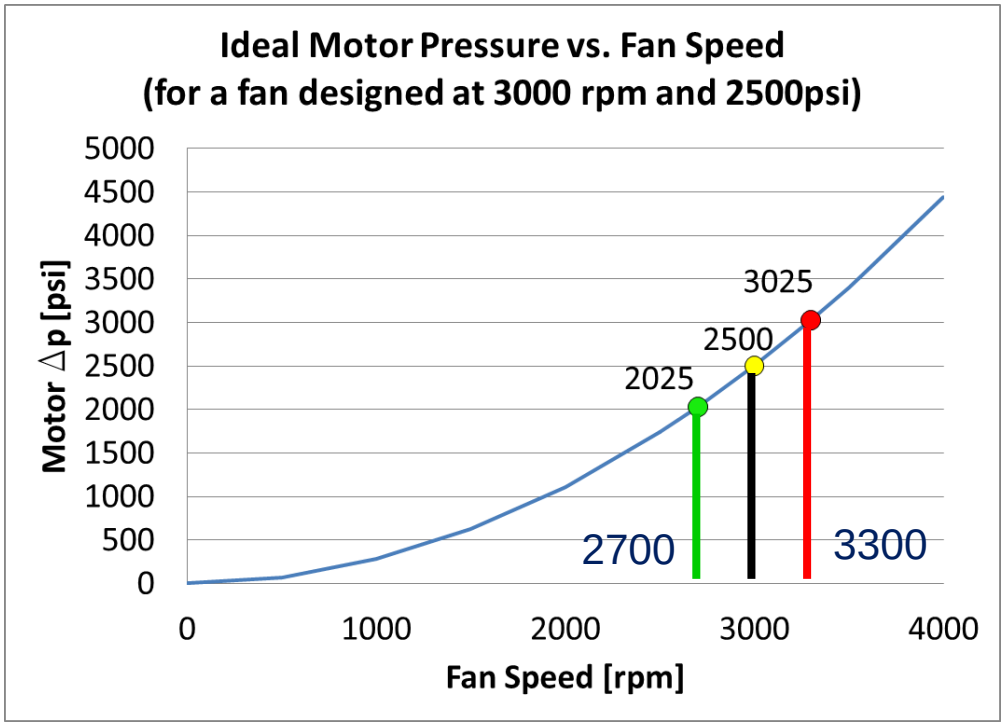
## Basic Hydraulic Fan Drive System



# Fan Drives in Mobile Hydraulic Applications

## Speed to Pressure Relationship

- Follows the fan torque curve
  - Motor pressure differential increases with the square of fan speed (ideal)
  - By controlling pressure difference across the motor, fan speed can be controlled



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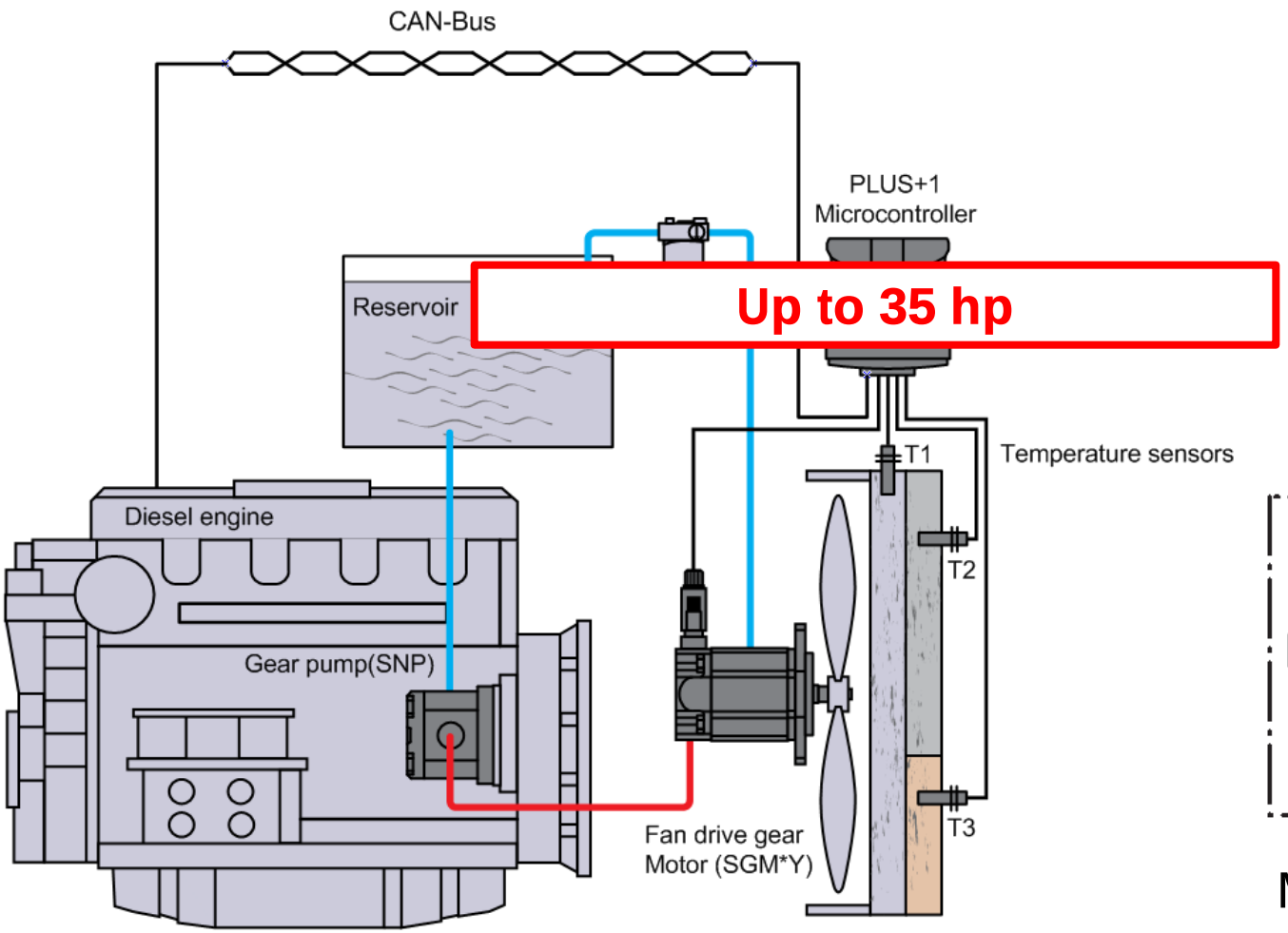
## Fail-safe systems

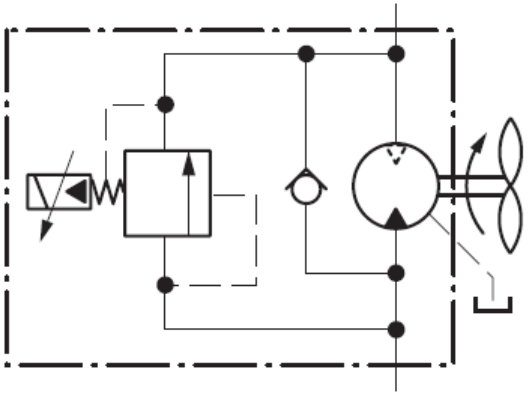
What happens when the control system fails?

The system must default to a full fan speed state

# Fan Drives in Mobile Hydraulic Applications

## Fixed Pump Fixed Motor System



Motor schematic



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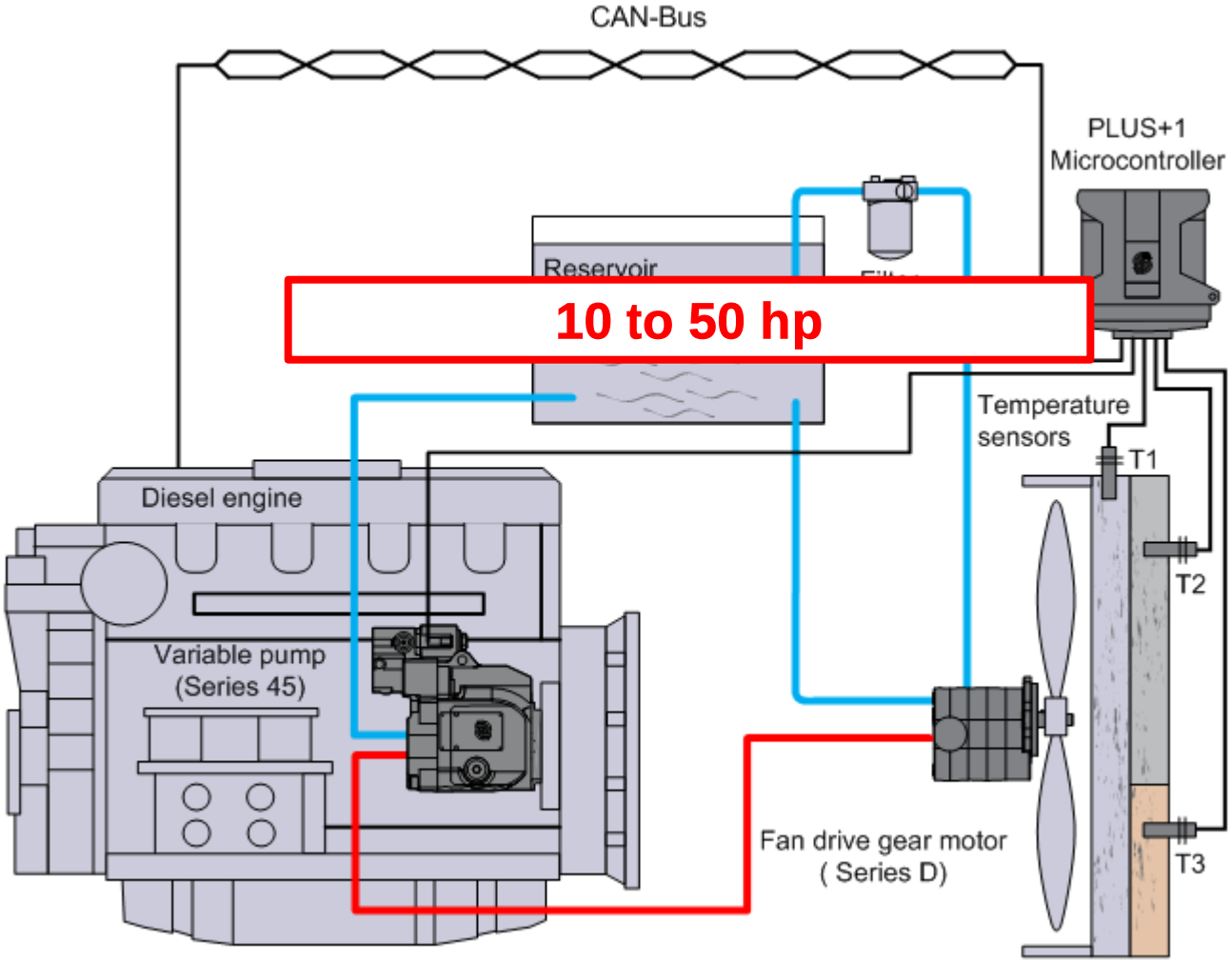
# Fan Drives in Mobile Hydraulic Applications

## Variable Pump Fixed Motor System



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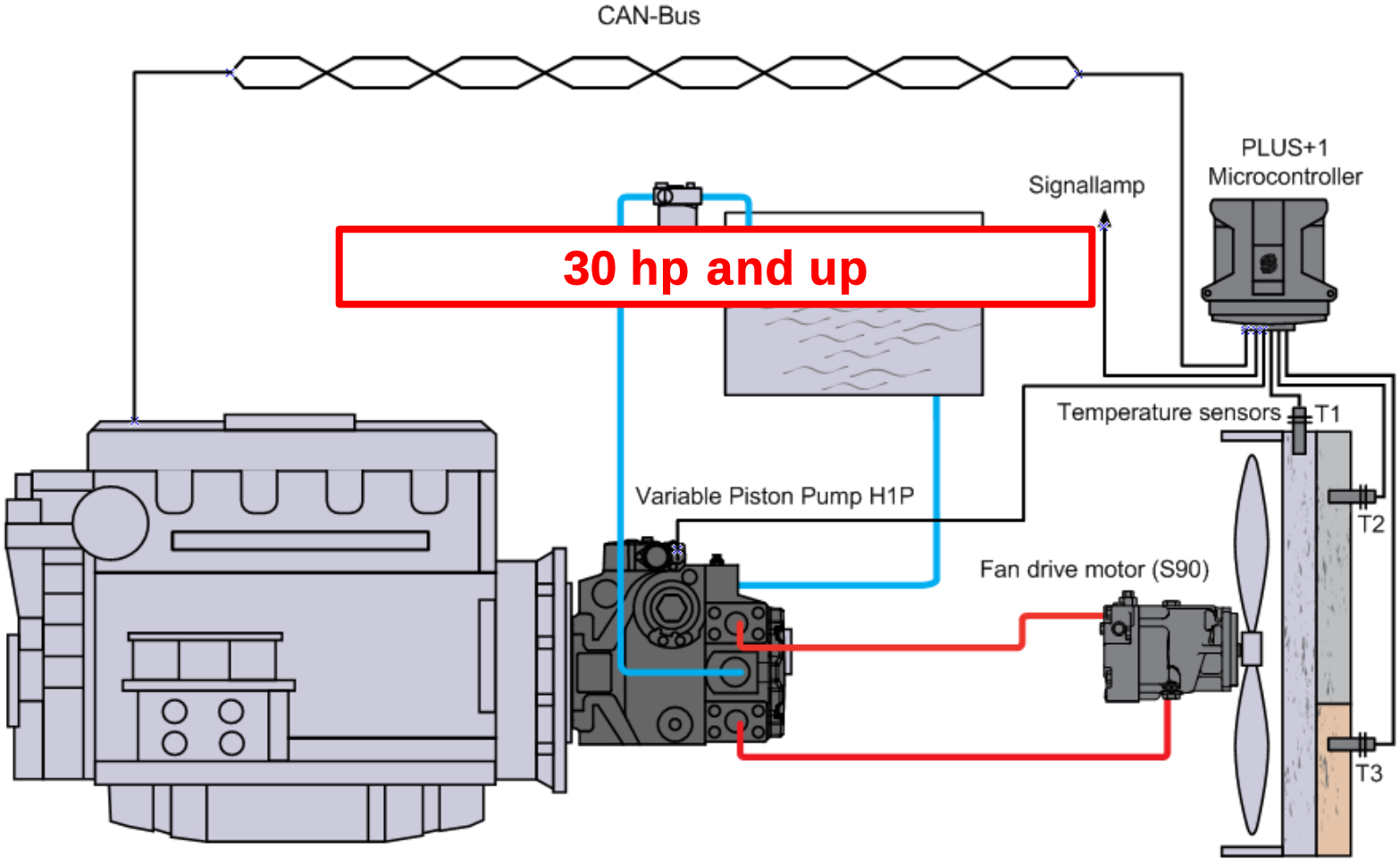
# Fan Drives in Mobile Hydraulic Applications

## Over Center Pump Fixed Motor System



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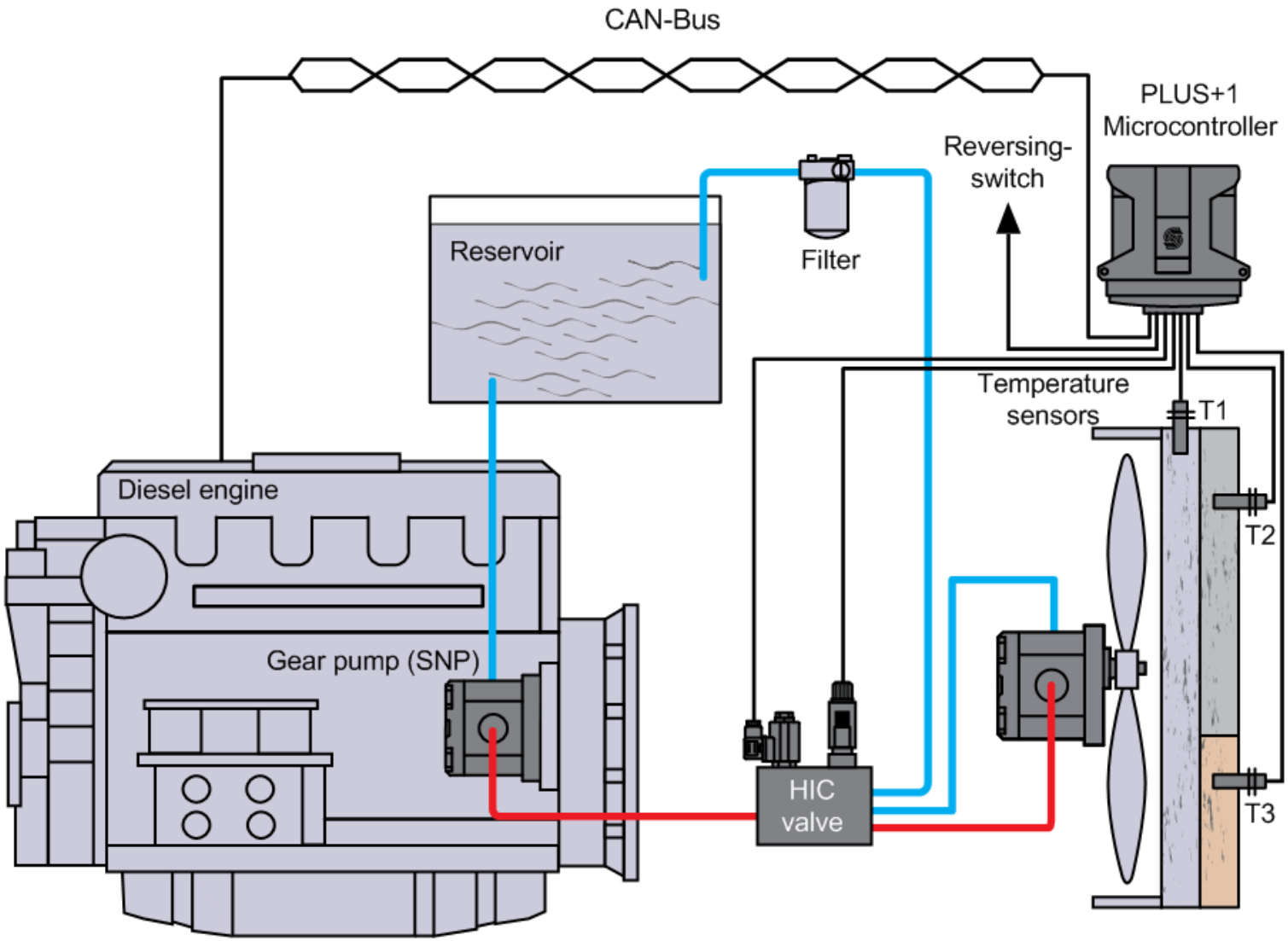
## Reversing Function

- Why would I use a reversing fan?
  - Agricultural, Construction, Forestry
  - Removes contamination to operate cooler at highest efficiency
  - Reduce manual blowout frequency
  - Remove washout water from radiator without getting into machine

# Fan Drives in Mobile Hydraulic Applications

## Fixed Pump Fixed Motor Reversing System

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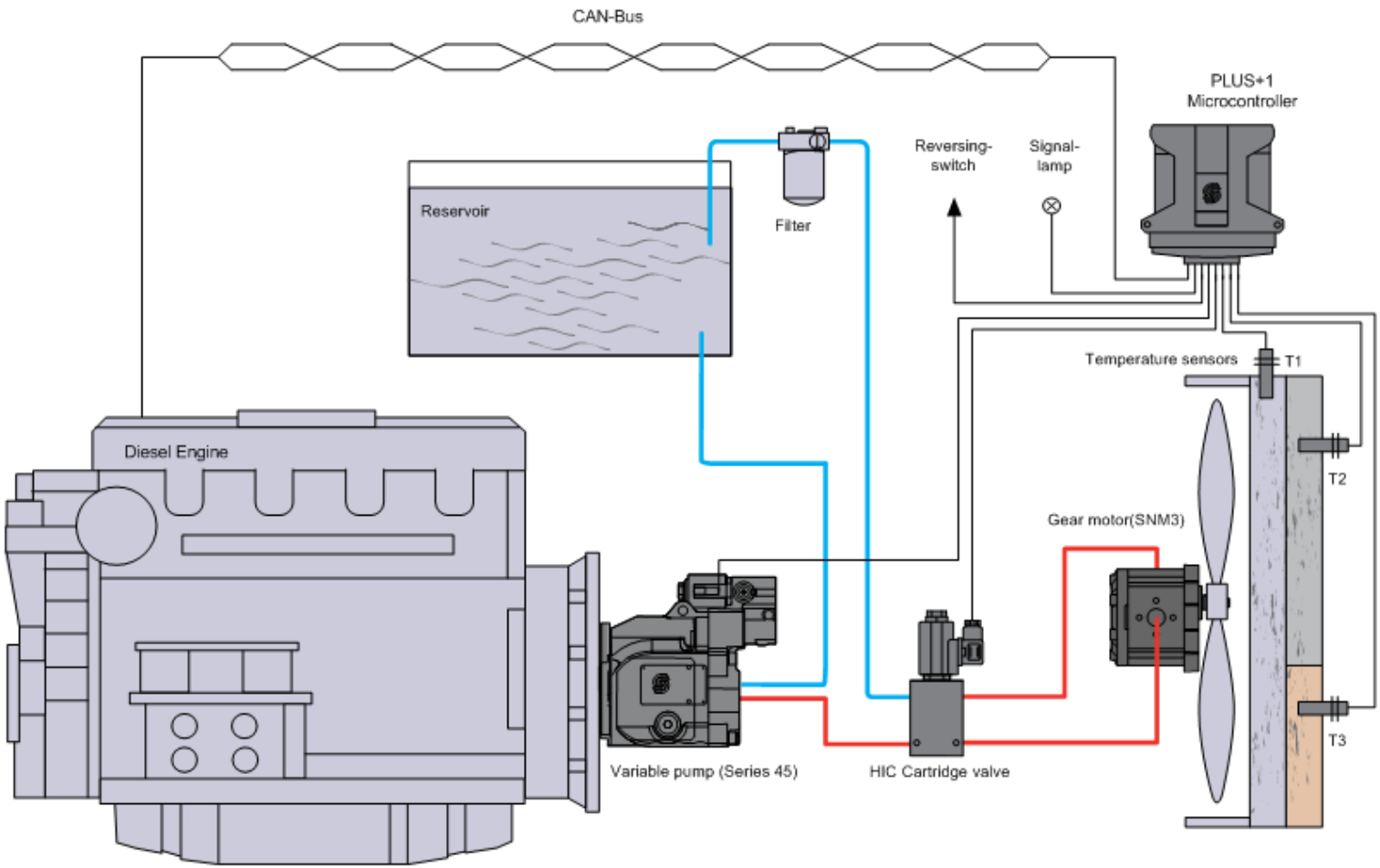
## Variable Pump Fixed Motor Reversing System



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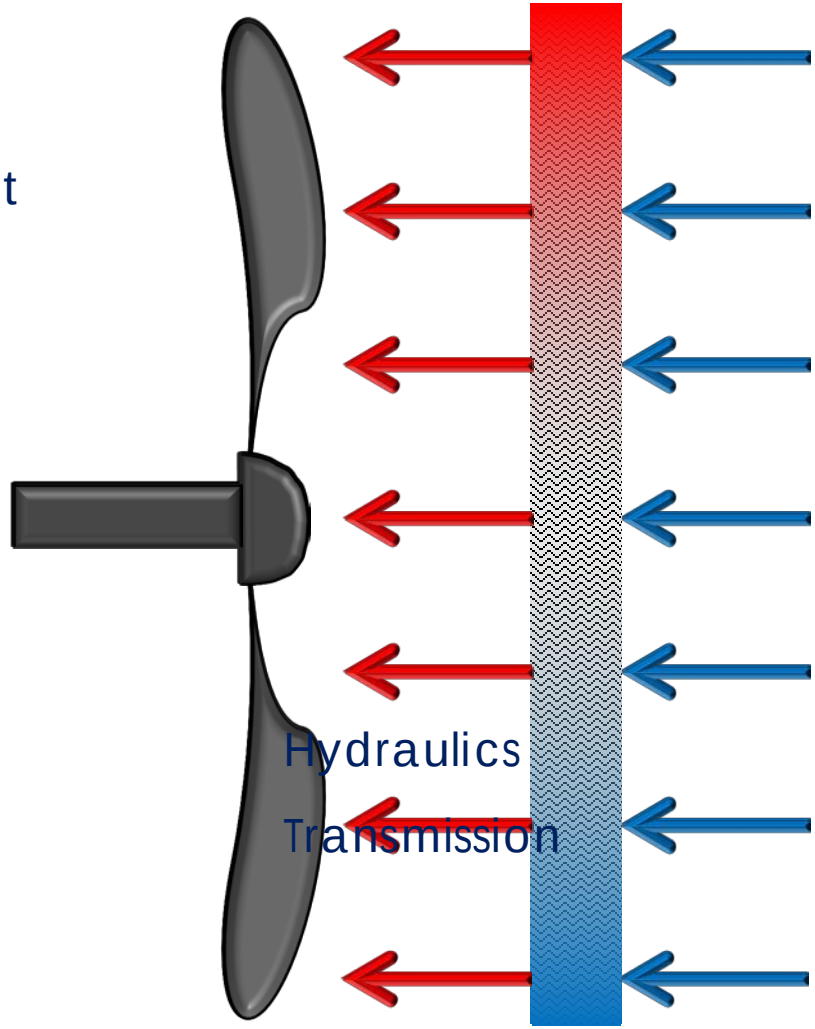
# Fan Drives in Mobile Hydraulic Applications

## Distributed Cooling

Engine Coolant

EGR

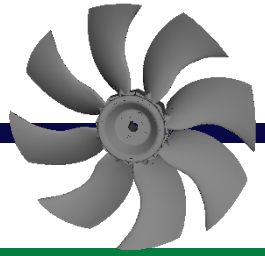



Divide and Conquer!!

A/C

CAC

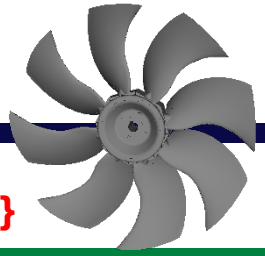
Power Electronics

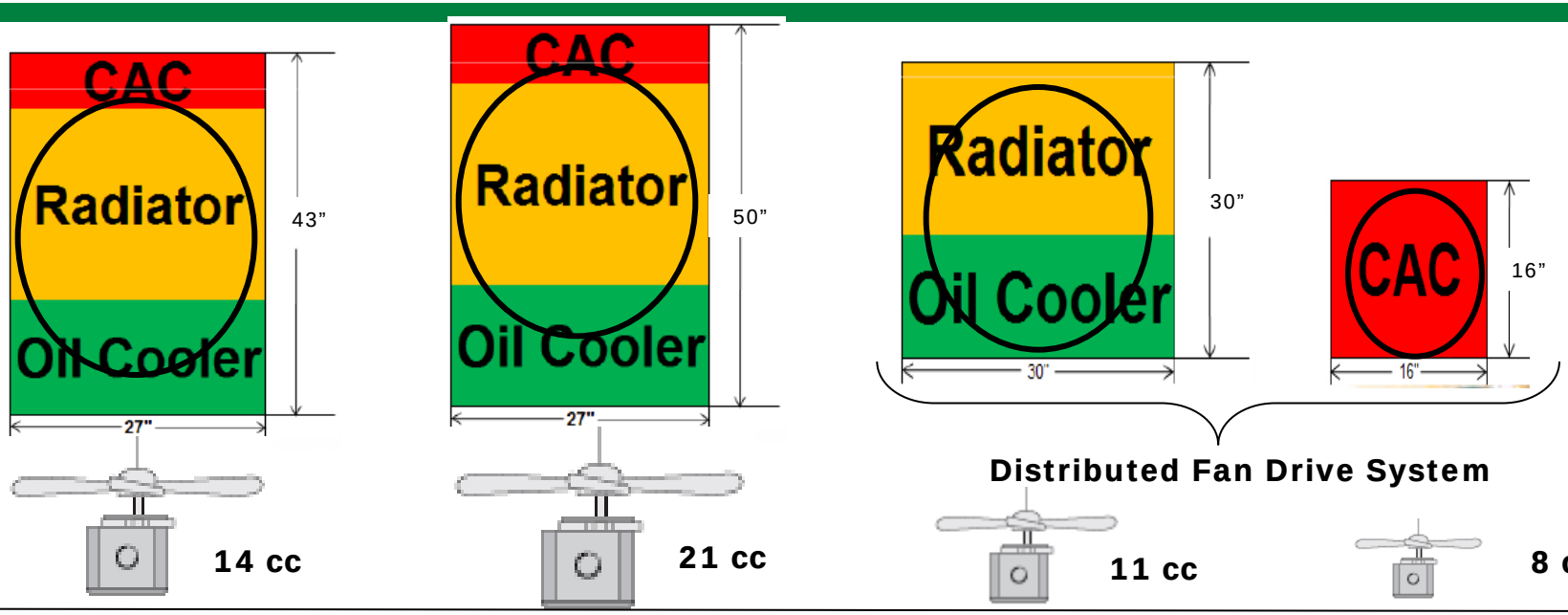


## Distributed Cooling

- Benefits:
  - Locate coolers closer to their heat sources
  - Smaller coolers can fit in tighter places
  - Each cooler can be cooled according to its need
    - Prevents overcooling of individual cooling systems
    - Better thermal control of individual systems

# Hydraulic Distributed Cooling Systems






| | Tier 3 | Tier 4 I | {Tier 4 I | Tier 4 I} |
|---|---|---|---|---|
| Fan Power | 12.5 HP Max | 23 HP Max | 9.6 HP Max | 1.3 HP Max |
| | 3.4 HP Avg | 6.3 HP Avg | 2.6 HP Avg | 0.3 HP Avg |
| Power From engine | 22 HP Max | 42 HP Max | 17.5 HP Max | 2.5 HP Max |
| | | | 20 HP | |
| | | delta 22 HP | | |
| | 8.1 HP Avg. | 15.9 HP Avg | 6.8 HP Avg | 1.0 HP Avg |
| | | | 7.8 HP | |
| | | delta 8.1 HP | | |



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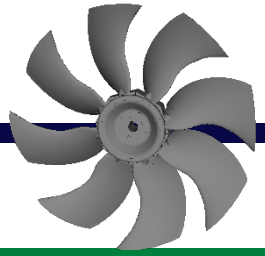

# Thank You

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