Why increasing demand for hydraulic Fan drives ?
(to cope with World Wide Emissions Regulations)

(For ''OFF ROAD'' Vehicles)



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Cranfield Presentation

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Background

Engine manufacturers are developing complete emmision control solutions to meet the ever increasing demand for cleaner exhausts

- Vehicle manufacturers selling machines in Western Europe, North America, Japan, and Korea are going through a continuing series of engine changes as the emissions regulations demand cleaner and cleaner exhaust gases.
- These changes have a negative impact on the cost, configuration, and operation of the machine.
- Vehicle Manufactures are currently transitioning through (Tier IV interim /Stage IIIB) of these changes; finally culminating in the most challenging transition - Tier IV final.

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What are the Emissions Regulations?

'**Tier'** in America and '**Stage'** in Europe

1994 – In USA the Environmental Protection Agency (EPA) and the European Parliament drafted standards for new off-road Diesel engines. These standards have been introduced already, and are now nearing the final stages

- 1999 – Tier 1 introduction
- 2003 – Tier 2 introduction
- 2006 – Tier 3 introduction
- 2014 – Tier 4 introduction



What is being focused on ?

Oxides of Nitrogen (NOx) gases are a bi-product of combustion – particularly combustion at high temperatures.

- When nitrogen oxide reacts in sunlight with certain organic compounds, such as methane, it forms smog.
- Combined with water vapor in the air, they produce acid.

ACID



RAIN

What is being focused on ?

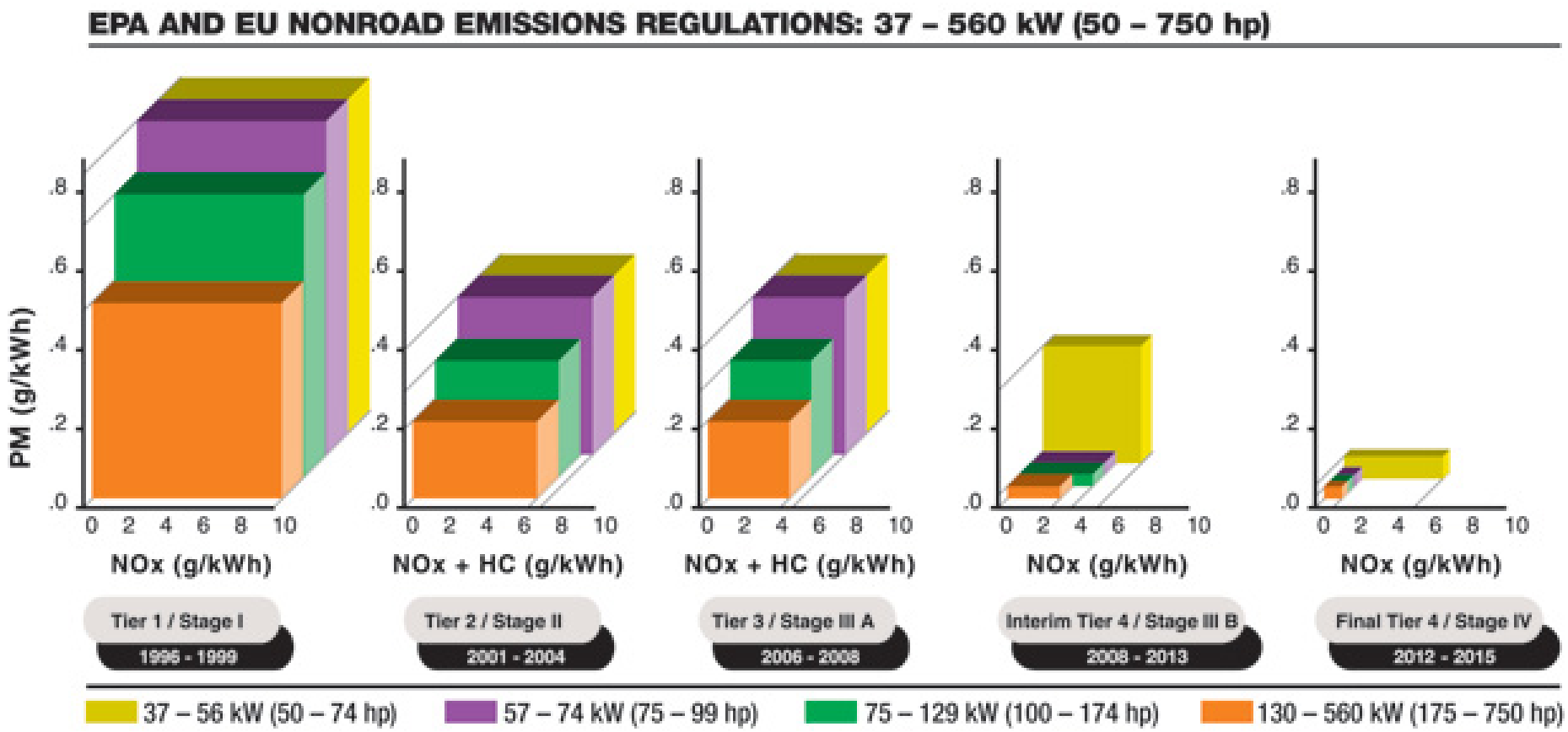
Particulate Matter (PM) are fine pieces of dust and soot that are suspended into the air.

- During the combustion process, PM mixes with exhaust gases to form an aerosol that is particularly harmful to people suffering from respiratory illnesses.



Engine Emission Regulation

Tier/Stage timelines



A Review of Tier II to Tier III

- From 2006 to 2008, off road engines in the range of 37 – 560 kW underwent a migration to Tier III emissions standards.
- This increased the water jacket (radiator) cooling requirement up to 20% for some engines and mandated the addition of a Charge-Air-Cooler (CAC).
- These changes required most OEM's to re-design or re-source the cooling packages.

Tier IV - Vehicle Designs

- Tier IV implementation will demand more engineering time than Tier III did
- Engine and After-treatment must be tested and certified as a complete installation
- Redesign of exhaust system is a BIG ISSUE.
  - Prepare for 300°C at the exhaust
  - Shielding of after-treatment devices will be required, 500ºC surface temperature
  - Stainless steel tubing to cope with chemicals and condensation
  - Need to reduce/eliminate joints (leak paths) in exhaust system
- Significant impact on Net Power, System Heat Rejection, and Engine compartment space

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Two examples of Tier IV engines fitted with exhaust treatment and cooling packages to meet the regulations





Tier IV engines are dwarfed by exhaust treatment systems, and larger cooling packages, and have increased electronic controls with associated sensors, wiring and micro-controllers to meet the legislation. This results in less useable power, and increased fuel consumption.

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Tier IV Final Predictions

- Tier IV Final engines will most likely employ SCR and EGR in combination.
- To reduce SCR consumption (Urea), exhaust NOx levels will need to be reduced even further.
  - This will likely be accomplished by increased EGR flow, which means **more heat rejection** from the EGR cooler.
- Heat rejection estimates are based on engine size.
  - <174 HP (128 kW) is estimated to be a 30-40% increase
  - >174 HP (128 kW) is estimated to be a 0-10% increase

Demand for fan cooling will increase

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Expected Impact of Tier IV

Engine characteristics will be affected

- Engine **application** operating speed reduced
- Engine **power** levels and **torque** will change
- System **heat rejection** will be increased

Tier IV Engine Emission

Expected Impact

At the Vehicle Level

- available hydraulic flow reduced, ~10%
- “NET” vehicle power output reduced, ~5% to 10%;
- heat rejected to the environment increase

  ~10-15, 40%;
- available installation space around engine reduced

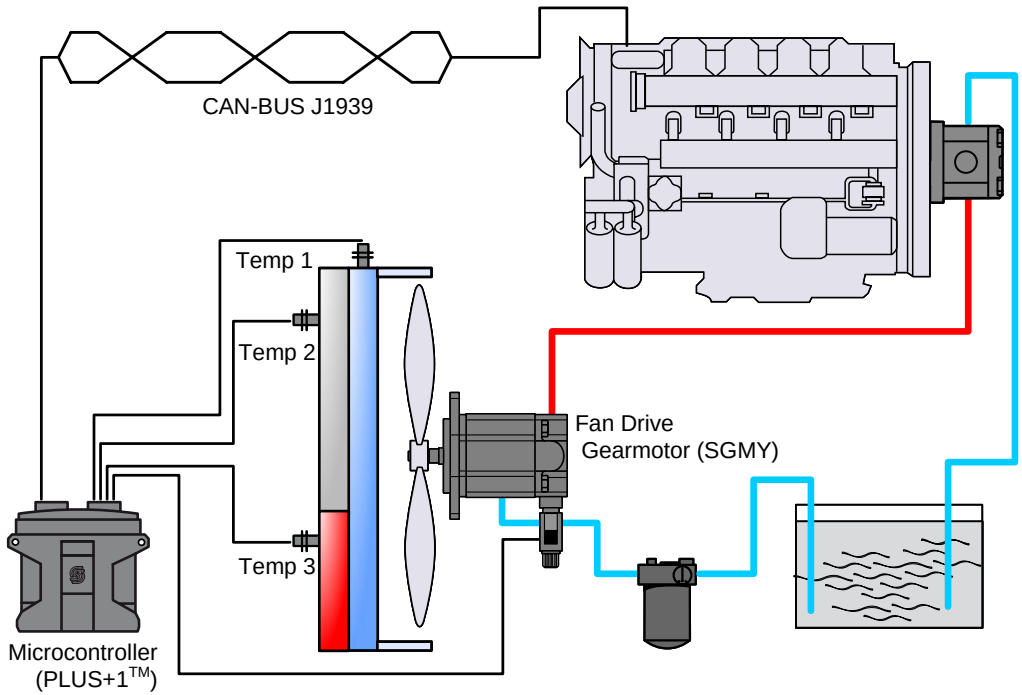
Vehicle manufacturers will need to update vehicle designs to account for all of these factors.

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Hydraulic fan drives are one of the solutions to control the increased demand for cooling

What makes up a hydraulic fan drive solution

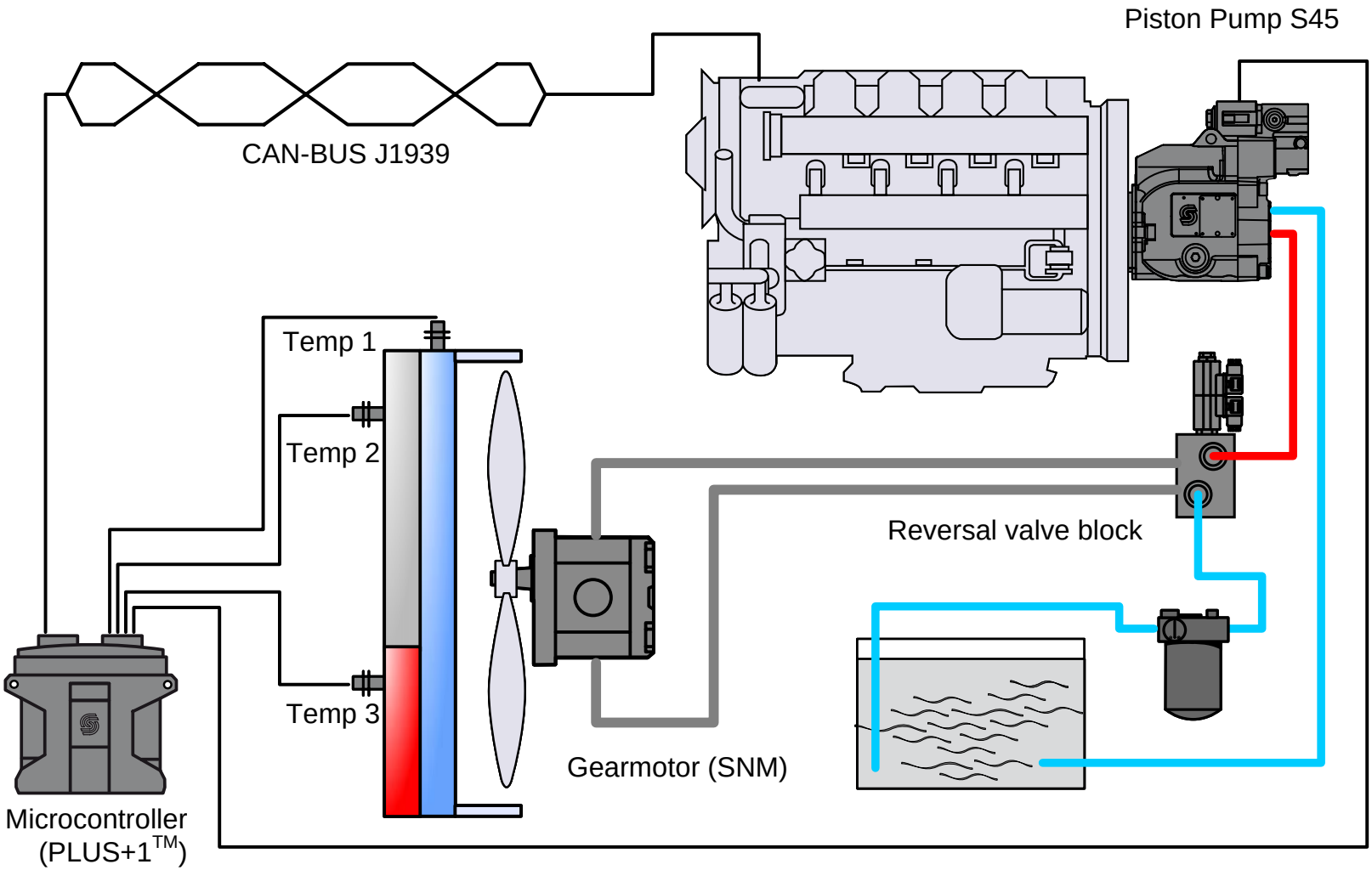
- **Hydraulic Pump**
- **Hydraulic Motor**
- **A Control Device**
- **Sensors**



We need to cool, the engine water and oil temperature, the charge air, and hydraulic oil

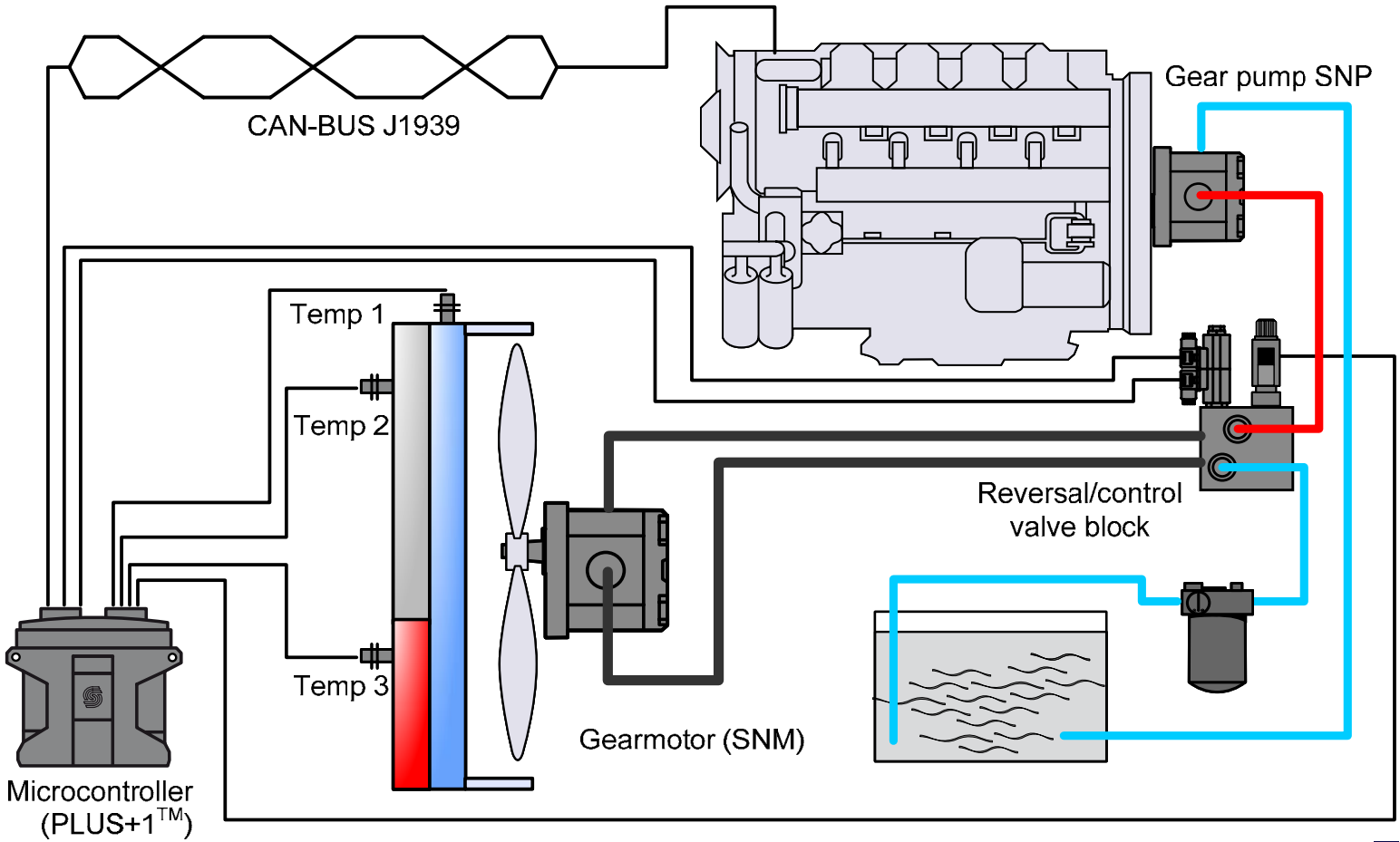
Fan drive system with variable pump

- improved efficiency over gear pump



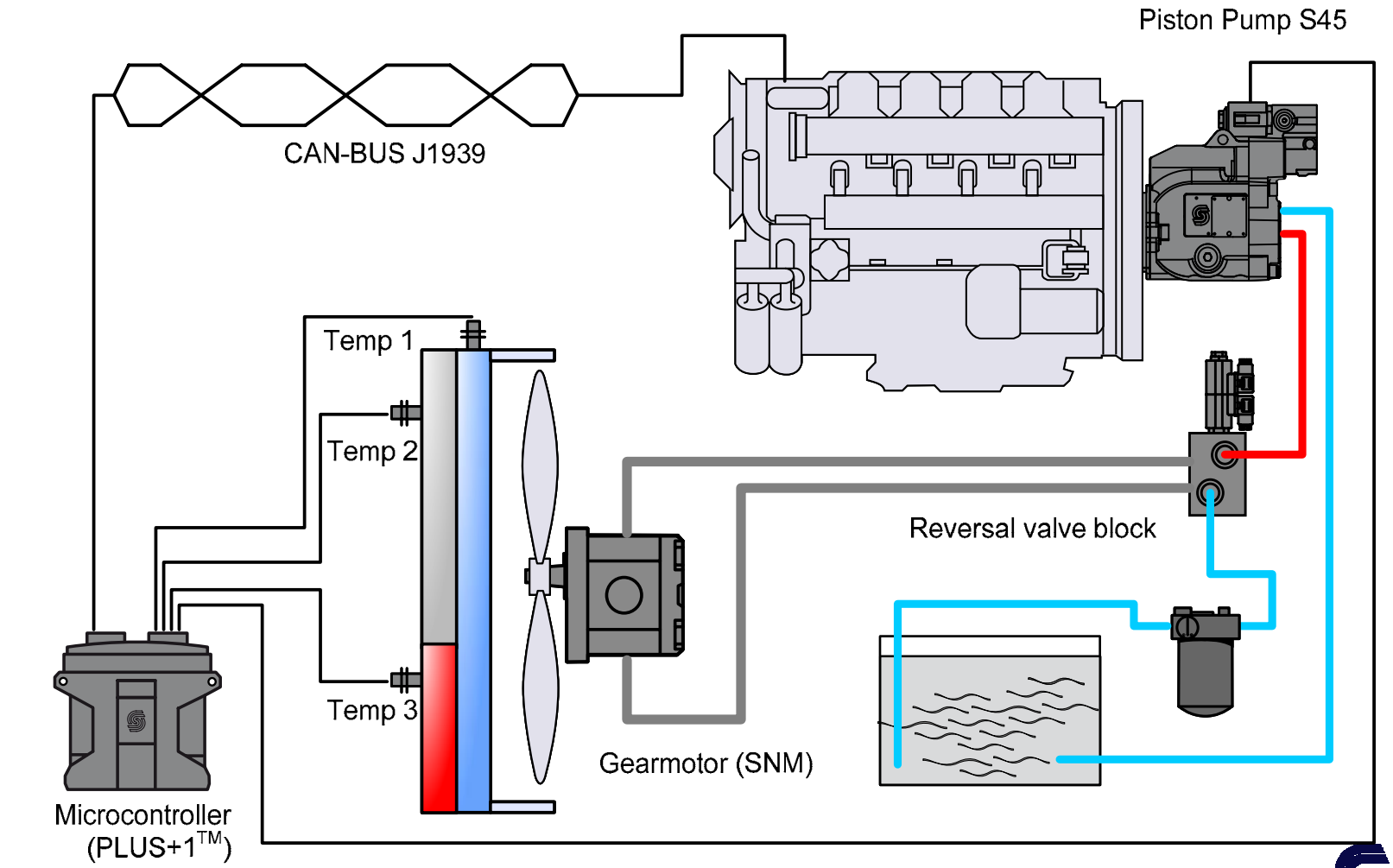
Fan drive system with gear product

- including reversing is cost effective at low fan powers



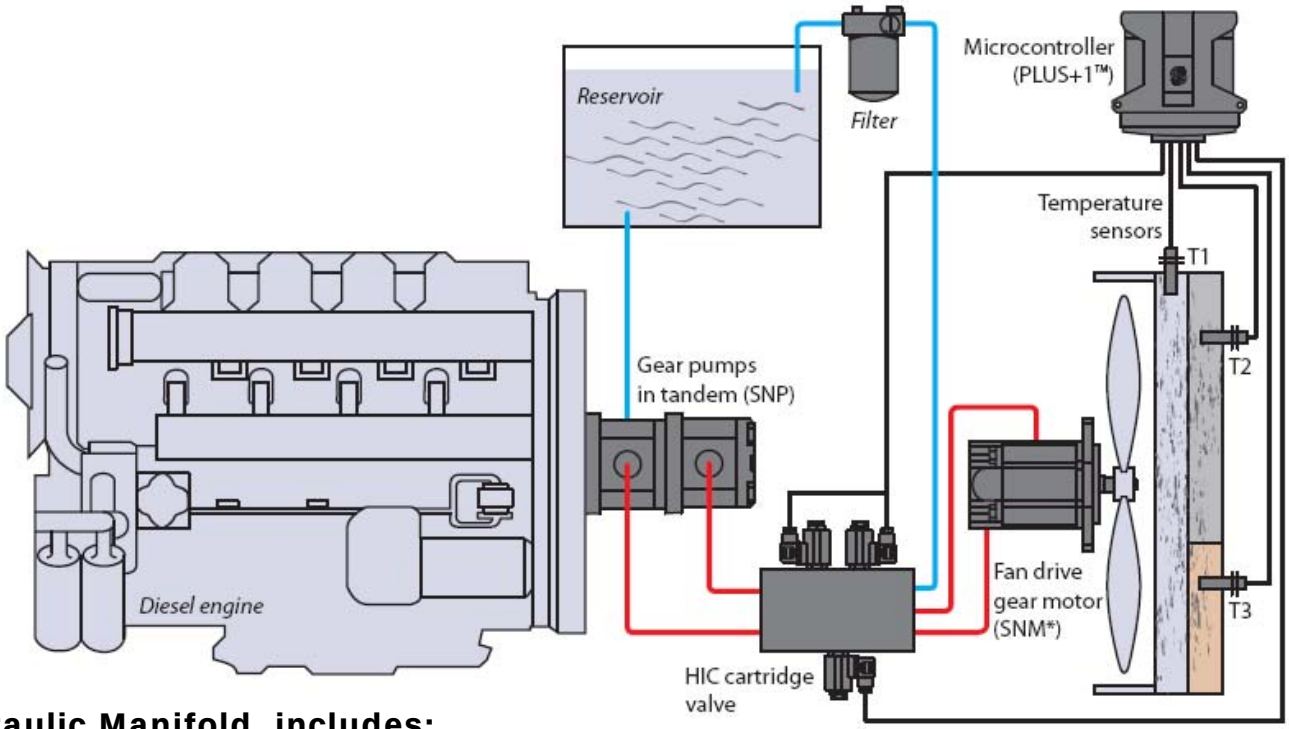
Fan drive system with Variable pump

-including reversing option gives optimum solution



Tandem Fixed Pump & Fixed Motor

- an alternative option for medium fan powers



Hydraulic Manifold, includes:

Unloading Valve for Rear Pump

Bypass Valve for Fan Speed Control

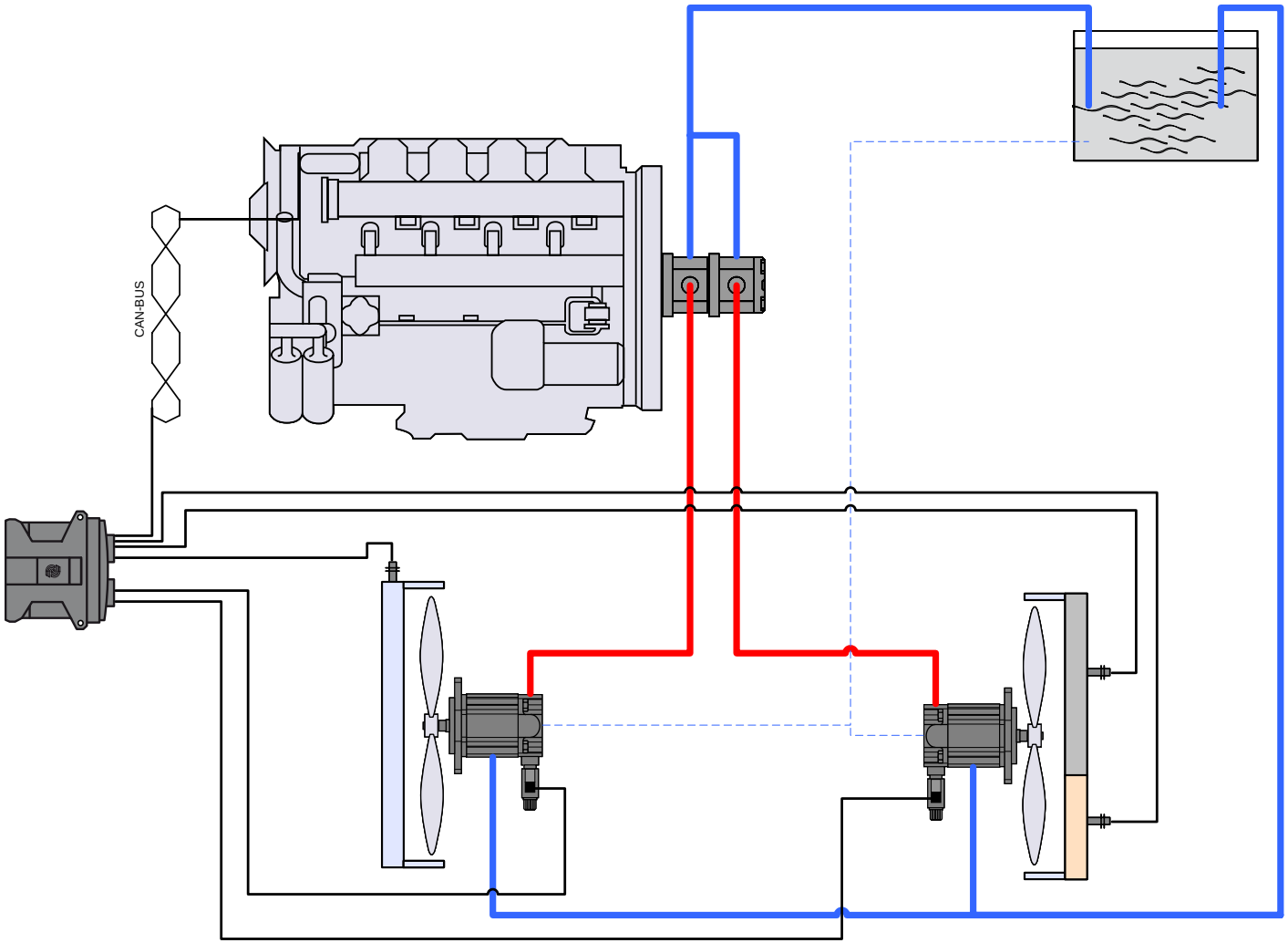
(Optional) Directional Control Valve for Fan Reversal

Reversing? Yes

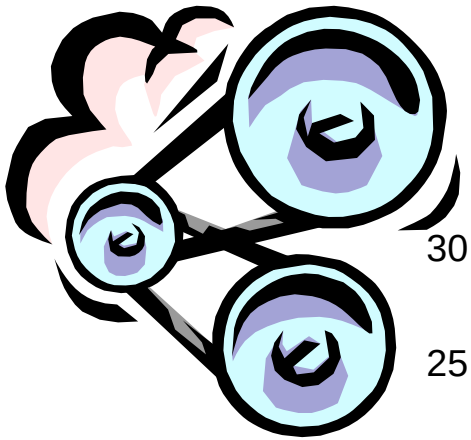
System Efficiency? Better

Fan drive system with two gear pumps

- used where it is more efficient to split the cooling

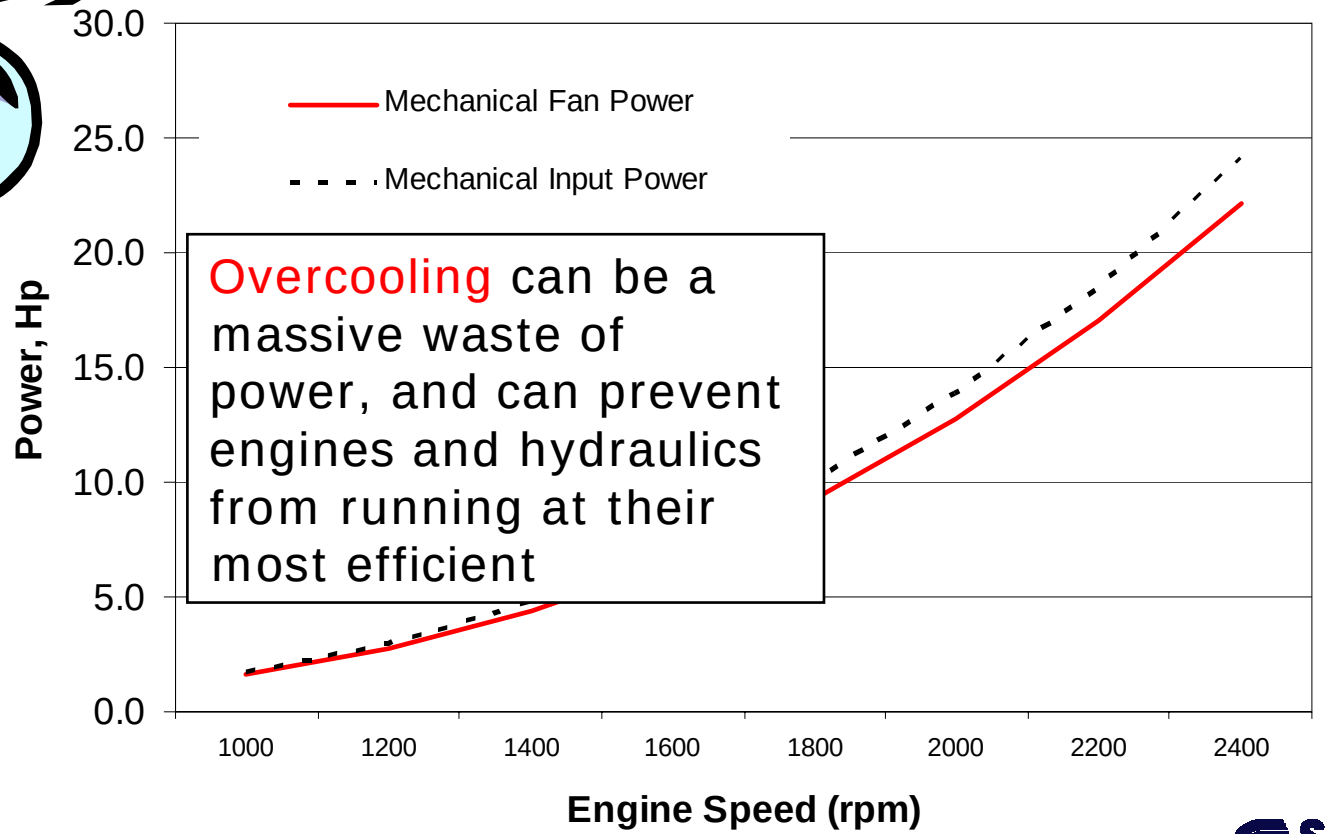


Mechanical Fan Drives – Not Flexible!!!



Belts are efficient, why change?

Fan Power = K x (engine speed)³ !!!!!!!!



Fan control – Flexible!!!

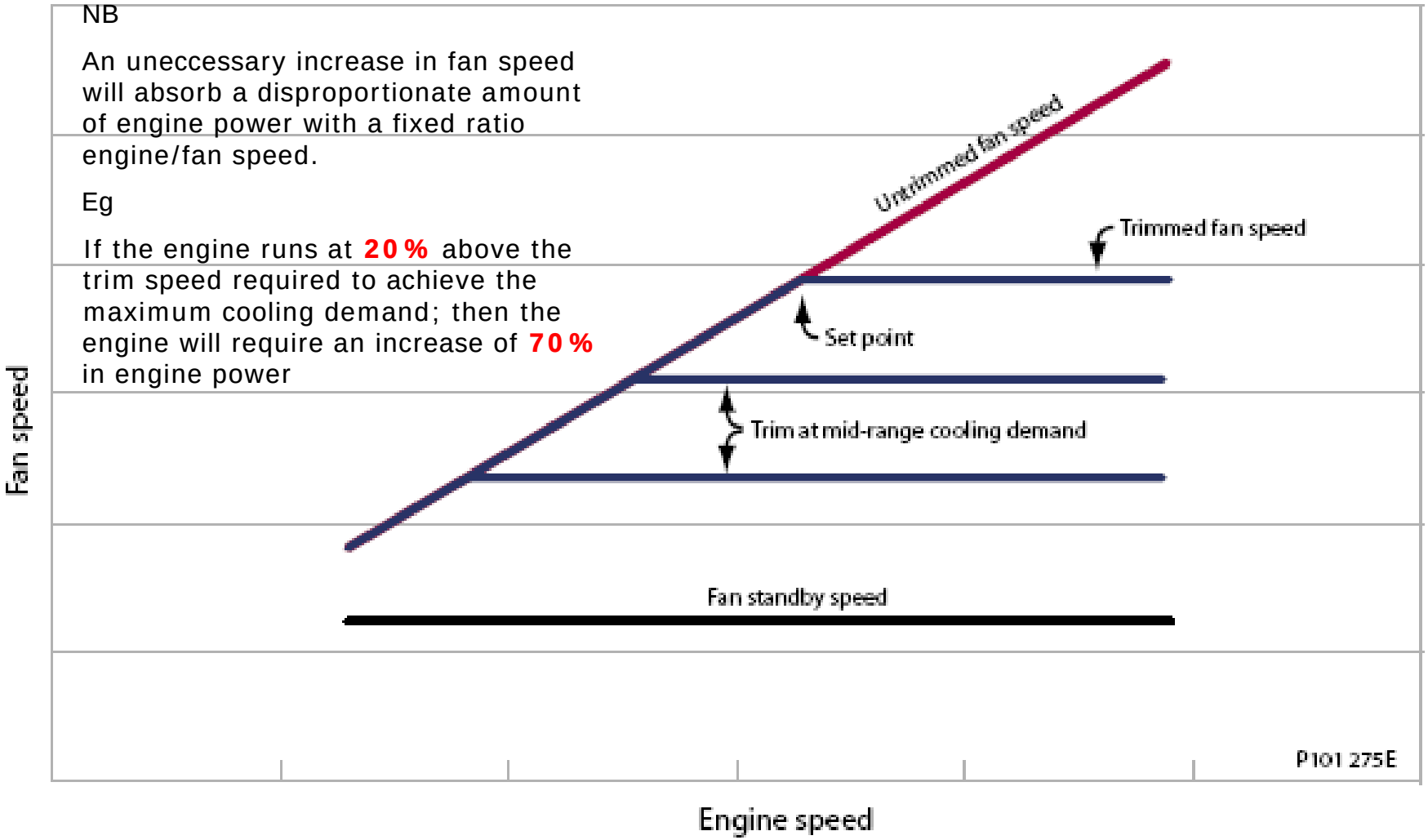
Fan Speed vs Engine Speed

NB

An uneccessary increase in fan speed will absorb a disproportionate amount of engine power with a fixed ratio engine/fan speed.

Eg

If the engine runs at **20%** above the trim speed required to achieve the maximum cooling demand; then the engine will require an increase of **70%** in engine power



System Benefits using S-D Modulating Fan Drive Systems:

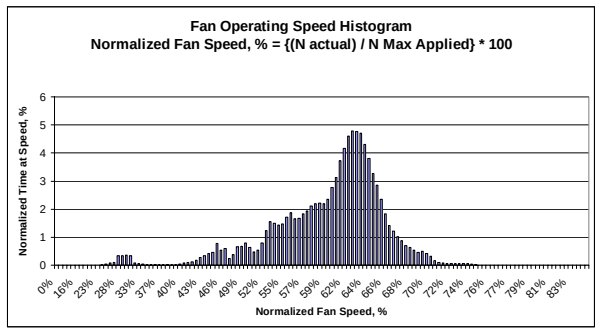
When fan speed is closely controlled by the engine's temperature,

it only operates at full speed

when the engine is at

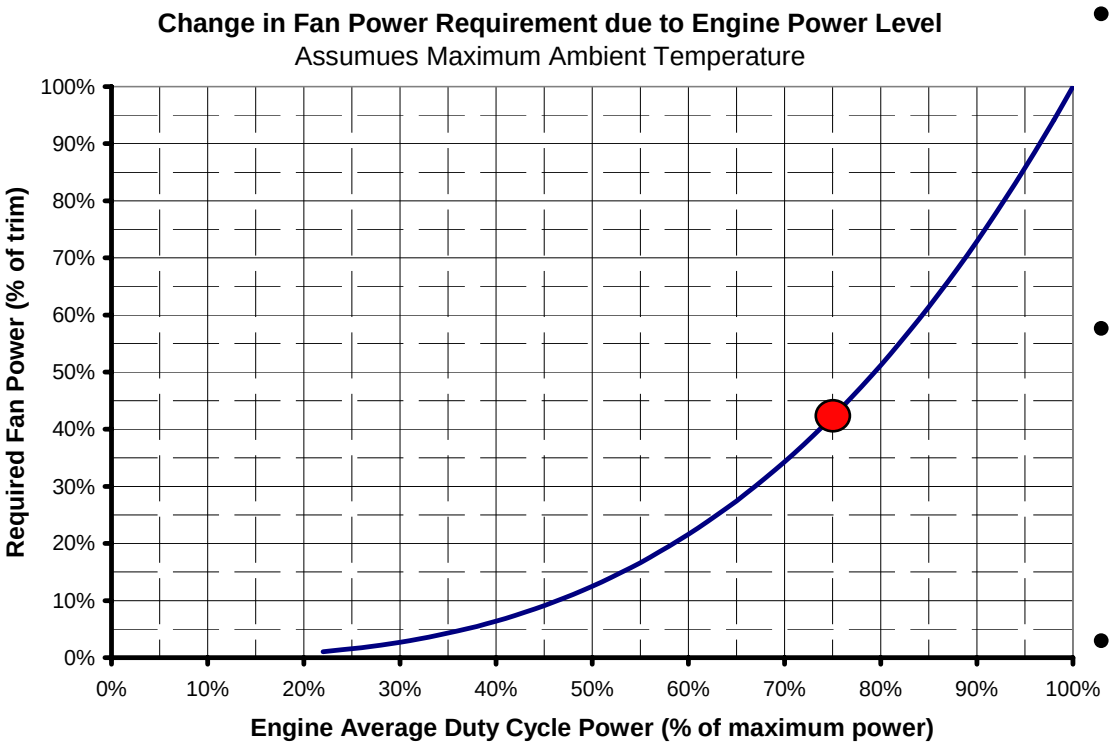
MAXIMUM Load and MAXIMUM Ambient conditions:

- Highest Ambient Temperature
- Lowest Atmospheric Pressure
- Lowest Relative Humidity,
- Highest Altitude
- Least available Ram Air Effect



Effect of Reduced Engine Power

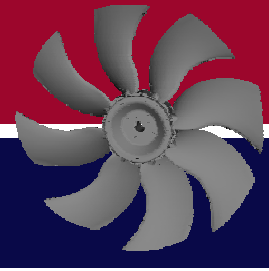
What if Engine is at Full Throttle, but not Full Power



- Scenario:
  - Machine at maximum ambient temperature
  - Duty cycle
    - Full power for 5sec
    - 1/2 power for 5sec
- Result:
  - When the system has high thermal inertia this rapid duty cycle looks like ¾ of maximum power continuously
- Fan Operation

System Type	Fan Speed (% of trim speed)	Fan Power (% of trim power)
Fixed ratio drive	100%	100%
Variable/Modulating	75%	42%

Ambient Temperature Example



- Assume:
  - Fan drive is designed for 50°C ambient temperature
  - Machine is doing work in Spain (Barcelona)

- August is the hottest month in this location with an average temperature of **29°C**

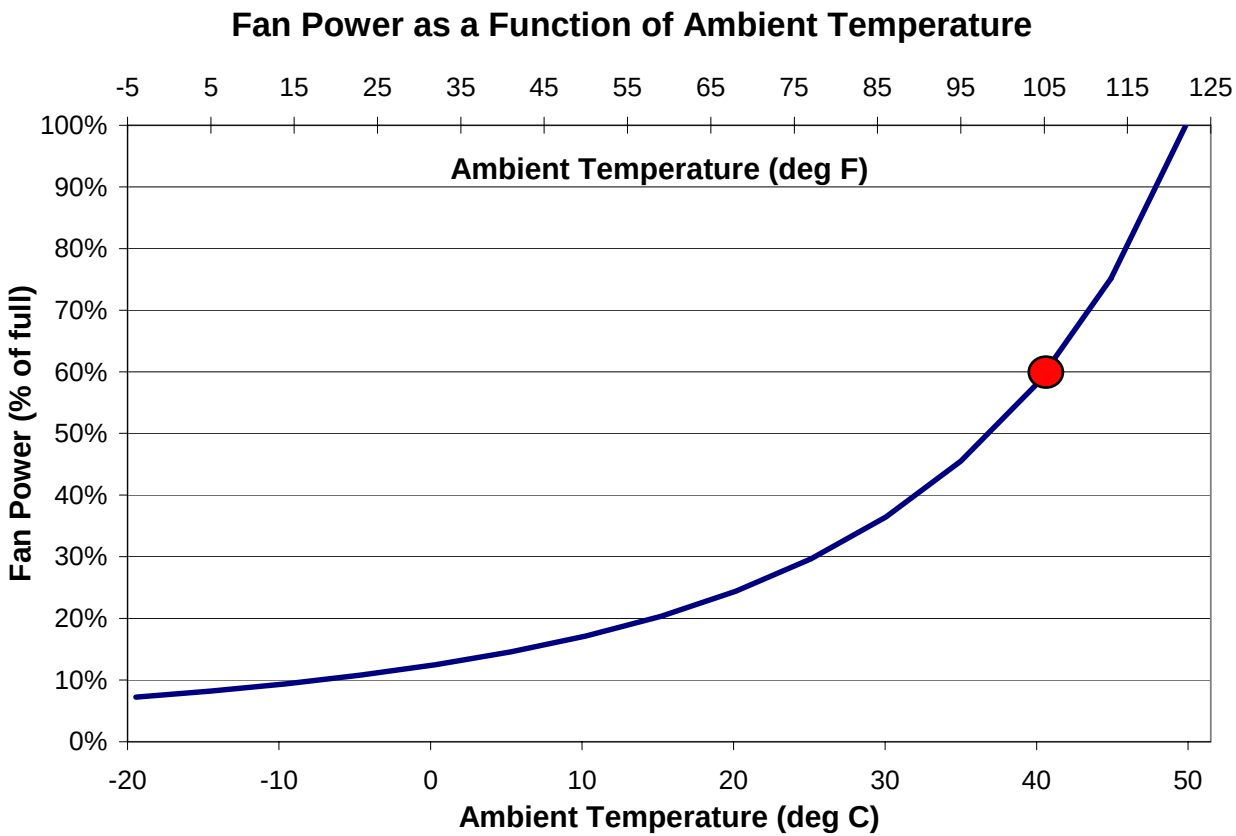
Month	Average Temperature °C	Average Temperature F
January	10	50
February	13	55
March	13	55
April	16	61
May	18	64
June	21	68
July	25	77
August	29	84
September	22	72
October	18	65
November	16	61
December	12	54

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Fan Power as a Function of Temperature

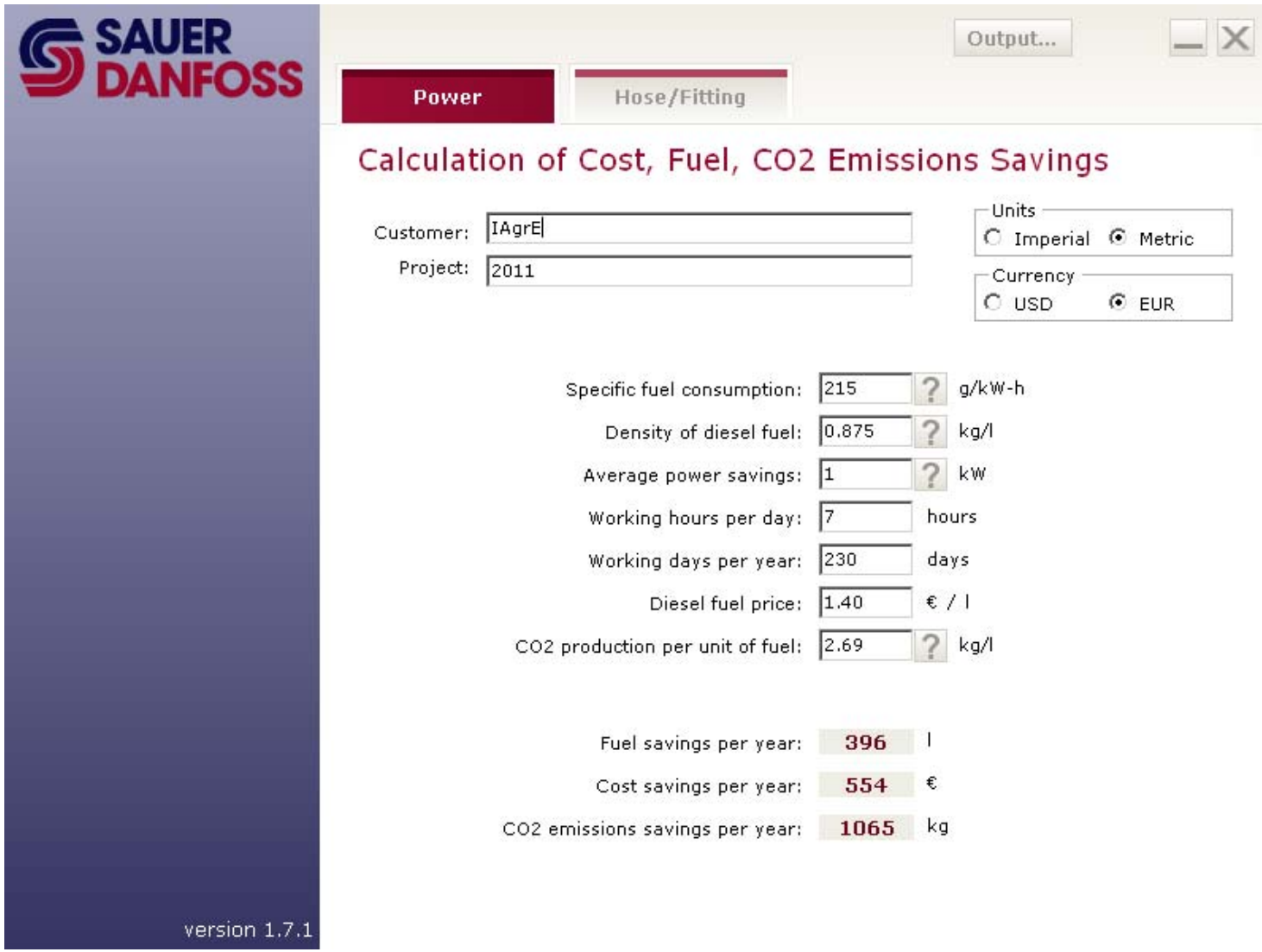
What impact does operating temperature have?

$$P_{Fan} = \frac{P_{Fan_max}}{\left(\frac{T_{Coolant} - T_{ActualAmb}}{T_{Coolant} - T_{MaxAmbient}}\right)^3}$$



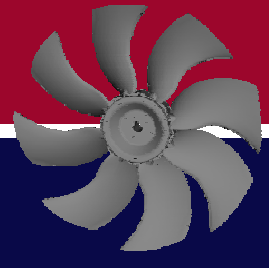
“More Productivity with Less Energy”

Cost of Wasted Energy (Power):



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Why would I choose a variable speed fan drive?



The Fan Runs at the Required Speed to Provide the Necessary Cooling

- Reduced noise
  - Legislative requirements
  - Customer satisfaction
- Reduced fuel consumption
- Reduced CO2 production
- More usable power available to machine/operator
- Mounting flexibility (hydraulic systems)

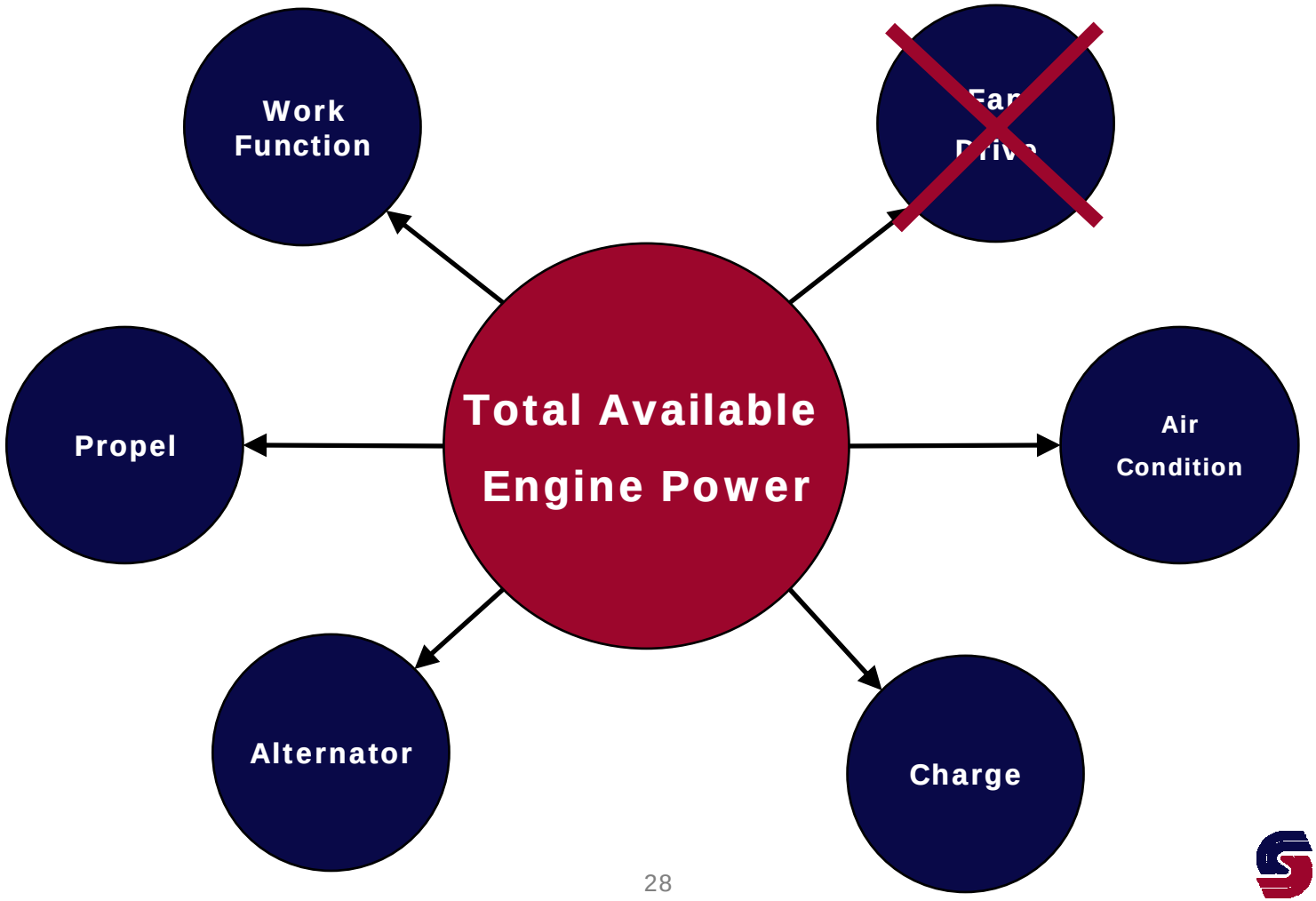
Project Purpose – What else can S-D do?

- *The WHY*:
  - Tier 4 will create need more efficient hydraulic systems
  - Sauer Danfoss is getting requests for solutions to recover or compensate for lost horsepower

- *The WHAT*:
  - Disabling hydraulic fan drive and allowing that power to be routed to other functions during peak engine load conditions.
  - In summary, vary power consumed by fan drive based on coolant temperature ***and*** engine load.

Project Purpose

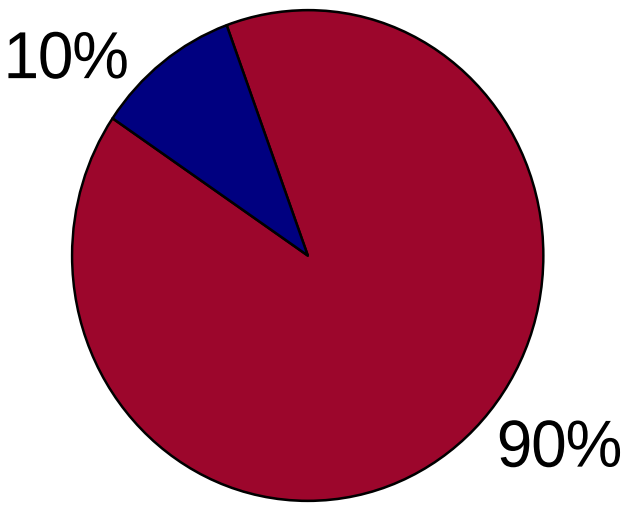
During peak engine loading…



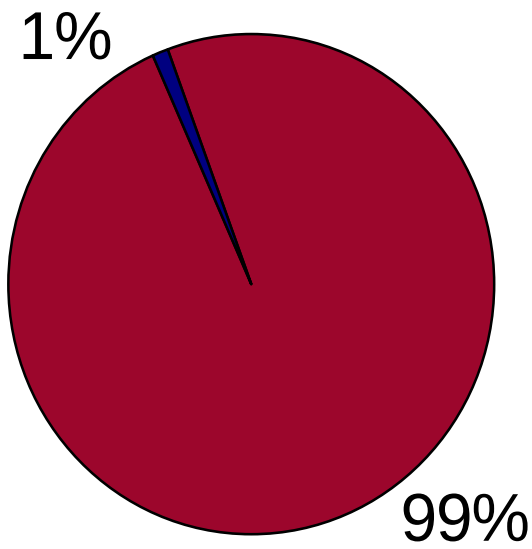
Project Purpose

Engine power distribution during peak loading

Original Engine Power Distribution



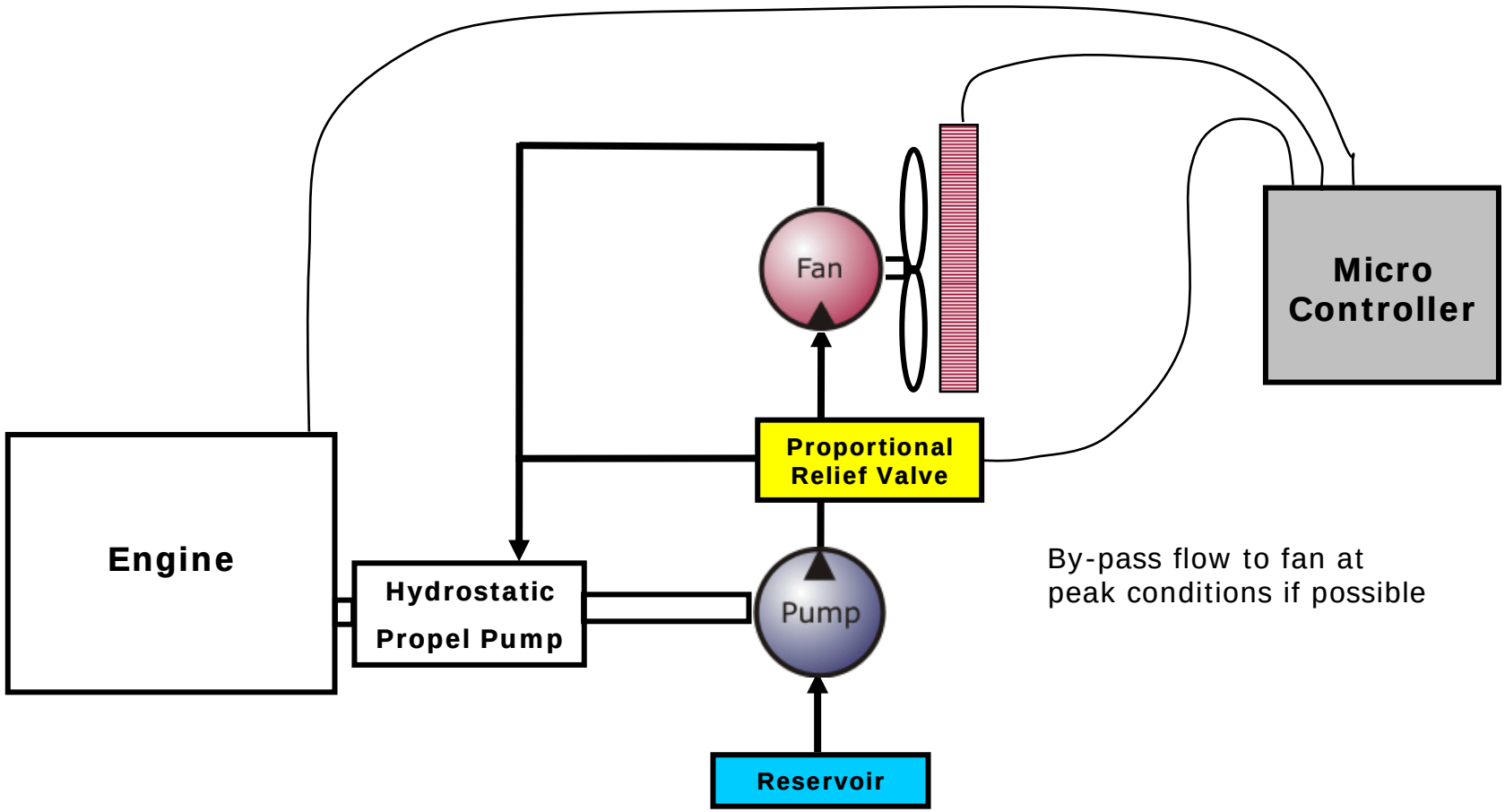
New Engine Power Distribution



Power Available for Work

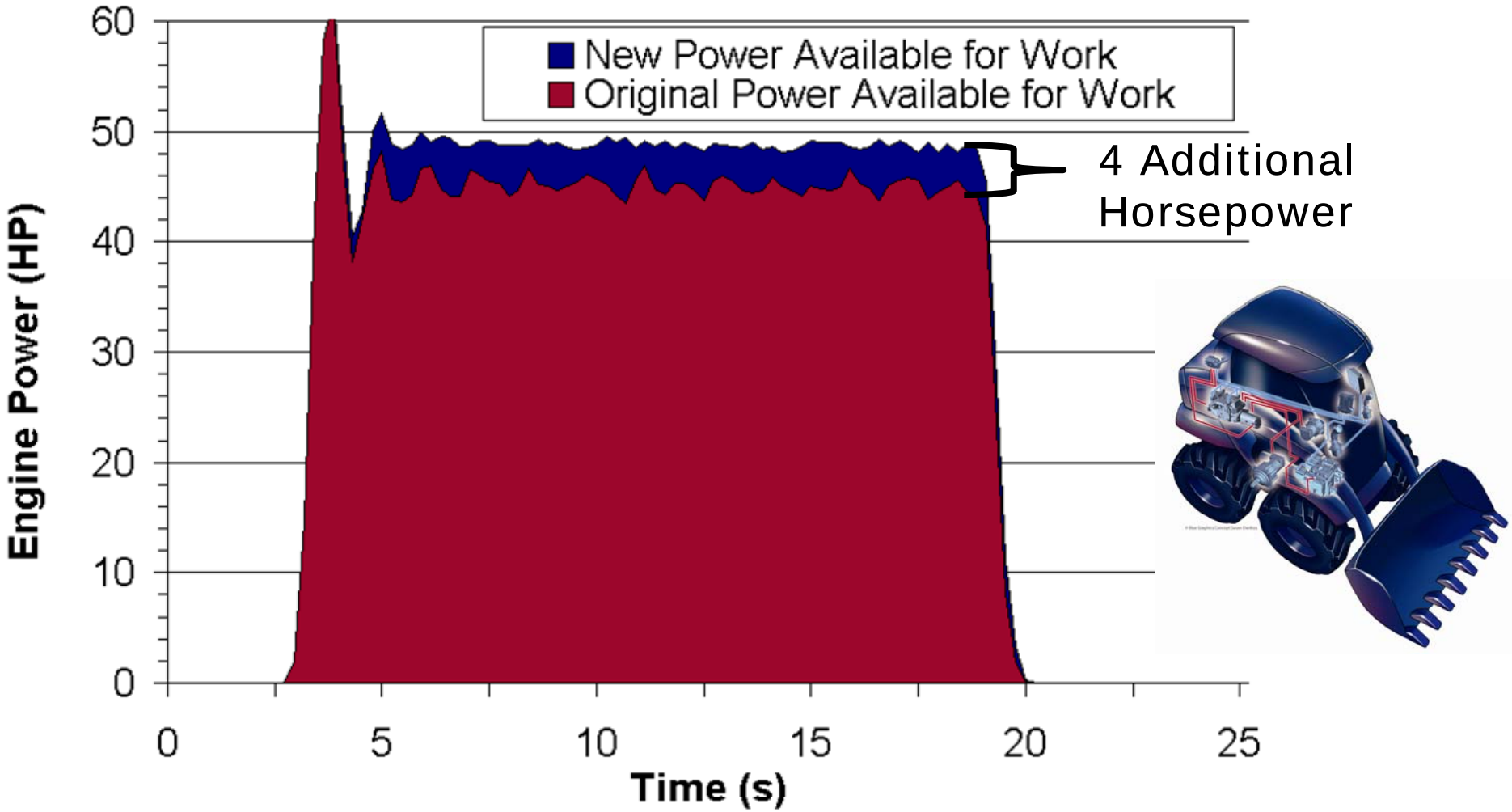
Cooling Fan Power

Circuit Explanation



Demonstration of Savings

With the ***same engine*** there will be ***more power*** to do work



Fan Power Priority Summary

- Benefits
  - 10- 15% Temporary Power Boost during peak load
  - Simple design. No hardware required with hydraulic fan drive system
  - Tested Concept and Verified Benefit
- Point of Awareness
  - Operator will notice audible fan speed change
  - Coolant/Oil average temperatures may run hotter

Benefit of Fan Power Priority in action



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A movie is worth a 1000 words ☺

Summary of TierIV transition

- The resource investment for Tier IV is estimated to be twice that of Tier III
- This change will affect multiple parts of the business – engineering, purchasing, manufacturing, marketing, suppliers,…
- Vehicle designs will require solutions that address Power, Heat, Space, Fuel, Efficiency, and costs.
- More emphasis on Vehicle total cost of ownership, rather than simple purchase price .

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Emissions Solutions

- Sauer-Danfoss is prepared to assist you in meeting the challenges associated with the Engine Emissions change.
- We will continue to identify and validate additional solutions.
- Please contact your Sauer-Danfoss representative for assistance.

Sauer-Danfoss Power Management Solutions

Sauer-Danfoss.com/emissions & IFPE 2011 New Tech



OEM Off-Highway

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Emissions Solutions

Over the next six years, new lower emission Tier IV and Stage IV engines will have significant impact on all future generations of off-road machines.

By our estimates, between ten and 15,000 different machines will need to be redesigned. Due to the complexity of meeting these regulations, the vehicle manufacturer is entering the most challenging phase of the emissions regulation cycle. Sauer-Danfoss has been diligently working on the technologies and performance variables related to Emission Certification. And we're prepared to partner with you – right now – to update your machine design – for greater productivity, using less energy.

In order to meet the required emission regulations, a number of engine

Superior Solutions

"We're looking for the best ways - the most efficient ways - to help customers design more productivity into their machines, while consuming less energy to get the work done."

Rick Sporrer,
Sales Quality & Technical Services Manager

Fan Drive Systems

Sauer-Danfoss offers you custom solutions in variable or modulating fan drive systems.

›› Learn more about fan drive systems

Global Impact

Between 10,000 and 15,000 different off-road machines will have to be redesigned in order to comply with Tier IV or Stage IV emission requirements.

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Local intranet 100%

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Thanks for your time and your attention!

