Danfoss Digital Displacement

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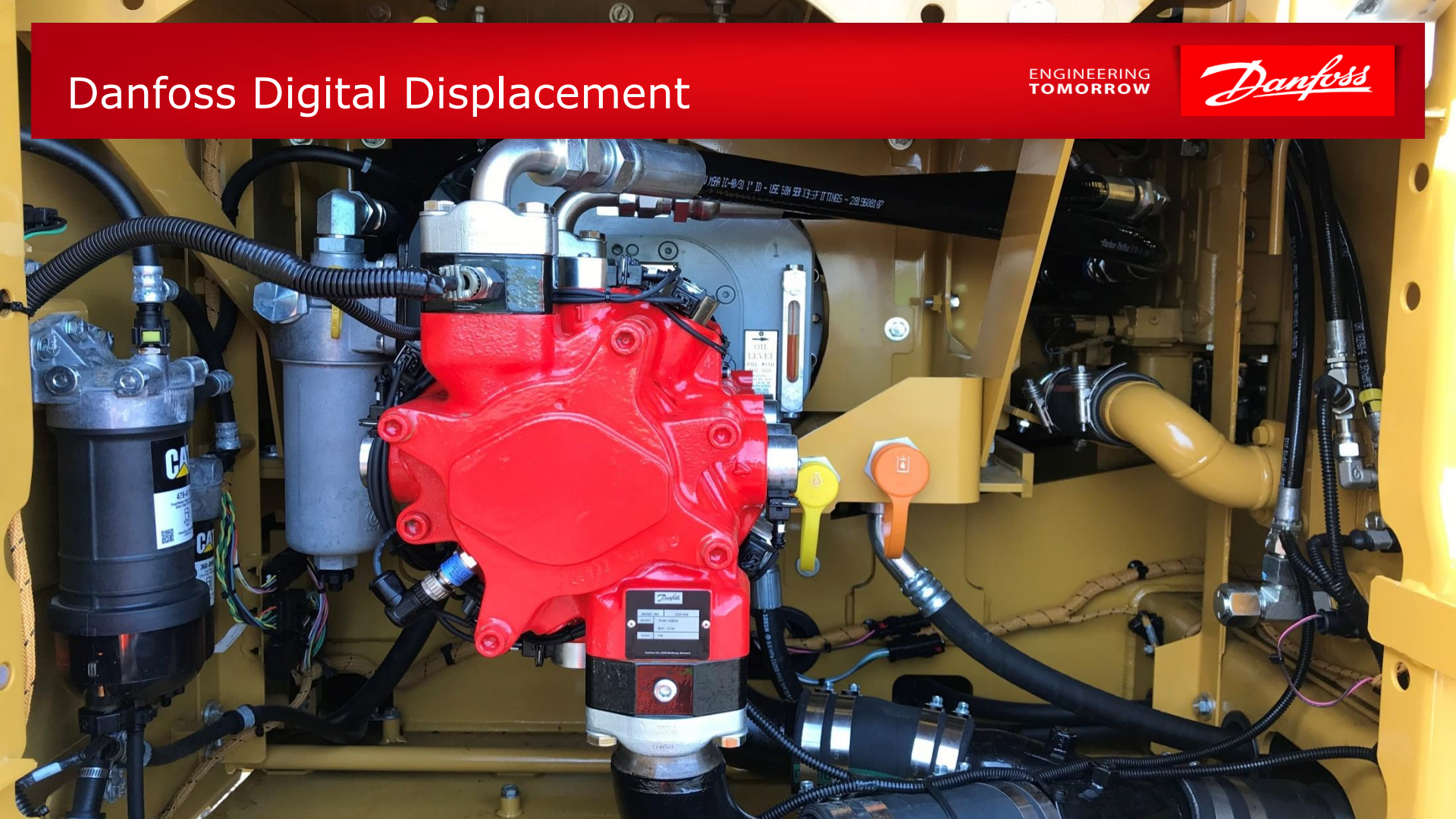
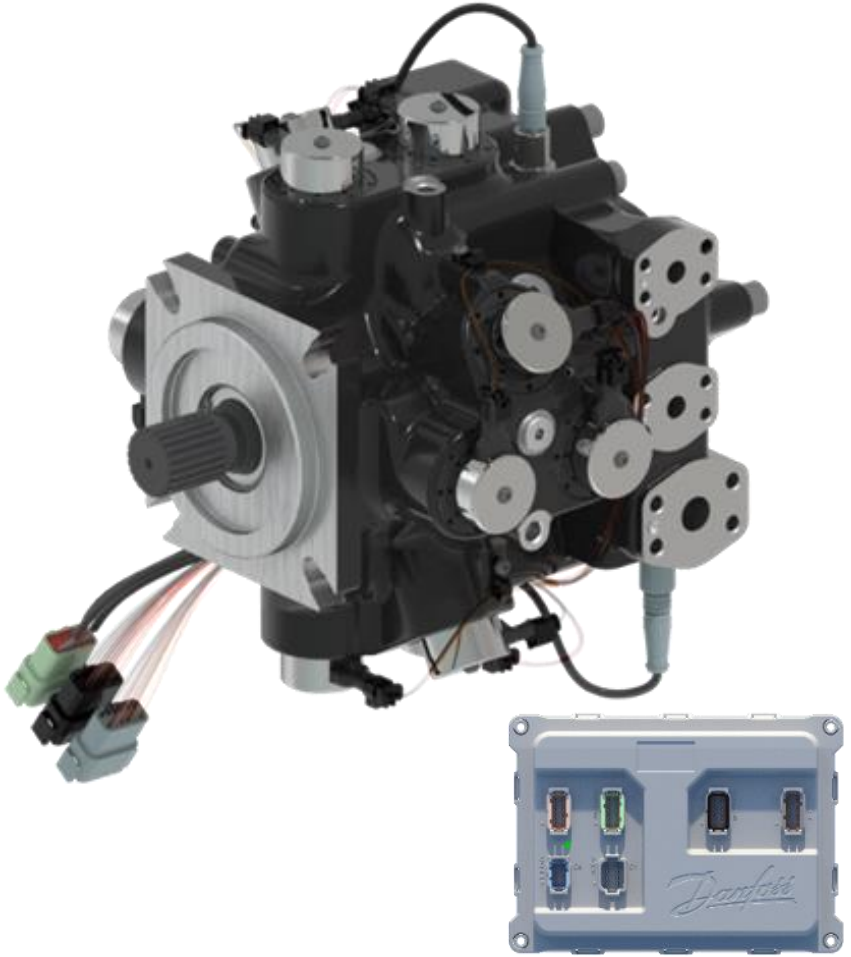


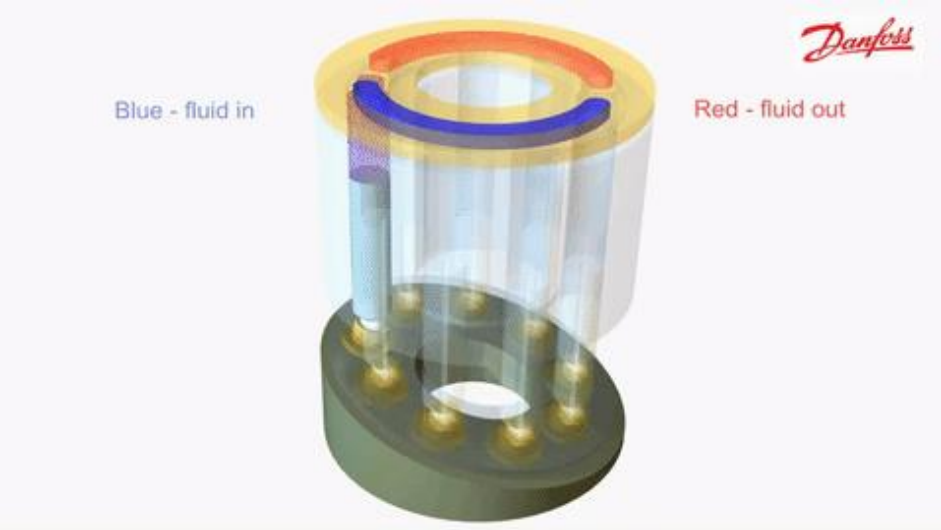
What is DDP?
Digital Displacement Pump

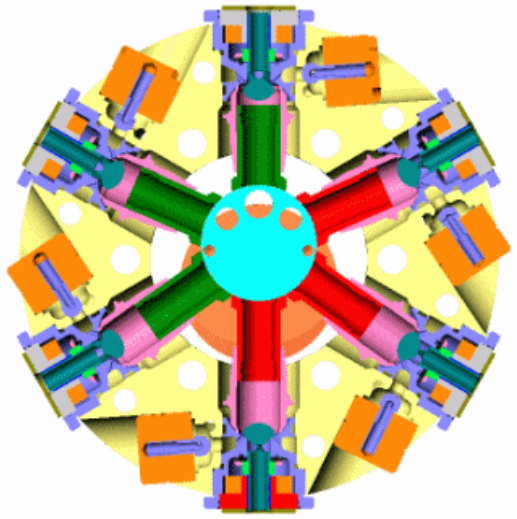
Overview

- Radial hydraulic pump with new control technology
- 96cc (5.86cir)
- Open circuit design
- 420 BAR (6,090 psi) pressure rating
- Static settings set by service tool
- J1939 CAN electronic control interface
- Integrated pressure, speed, temperature sensors
- Multiple independently controllable pumps option



What is DDP?
Digital Displacement Pump

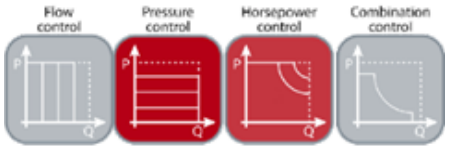




Axial Piston Pump

Digital Displacement Pump

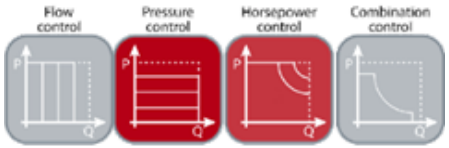
DDP Features



Unique Features

- Robotics-level control capability
  - Digital control of individual pistons
- Highest efficiency hydraulic pump available
- Fast and accurate response in 30 ms
- High efficiency – optimized radial design
  - 94% peak efficiency
  - >90% efficiency across a very broad range
- Very low idle losses
- Starts off-loaded
  - Industrial: Reduced need for industrial infrastructure
  - Mobile: Reduced engine torque for cold starts

DDP Features



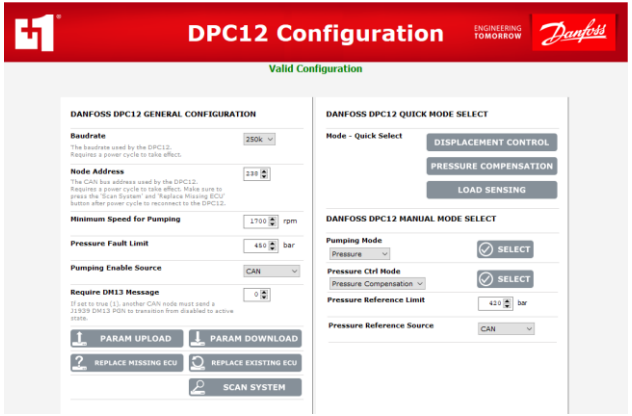
Unique Features

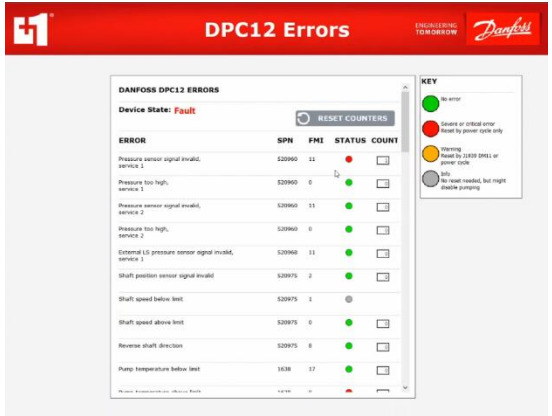
- Capable of multiple separate outputs from one pump
- No hysteresis
- Control modes and parameters are electronically tunable
- Independent flows and control modes on each outlet
  - Displacement control
  - Pressure control
  - Load sense
  - Pressure compensated
  - Horsepower limited

What is DDP?

Software control and configuration

- Easy setup of DPC12 controller with a software Service Tool
- Communication over CANbus via Danfoss CG-150 gateway
- Service Tool pages to access functionality in a clear way



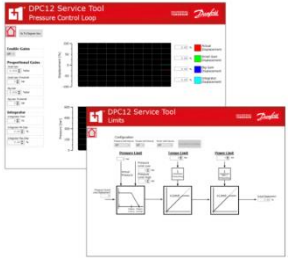


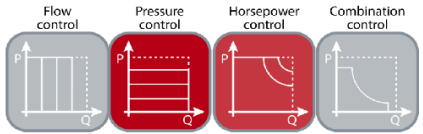
What is our Current offering

‘Single’

‘Multi’

‘Tandem’

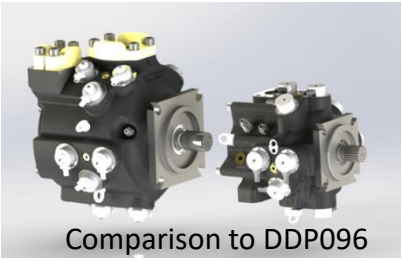




Future Product Direction

Modular DDP – **DDP1X0**

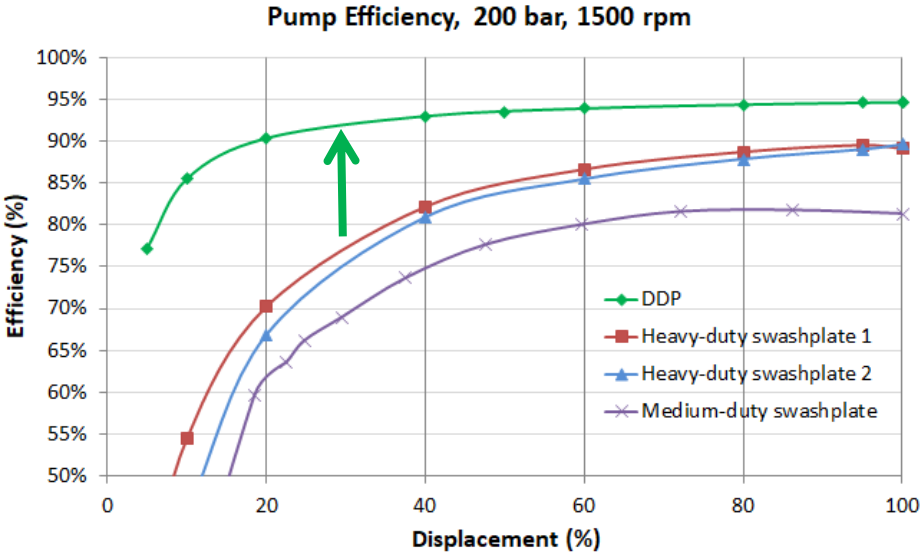
- Modularity at a piston and valve level
- Broad range of displacements
  - (2x) 120 to 180 cc/rev
- Excavator as initial target market
  - 1 - Start with pumps
  - 2 – Develop multi-service
  - 3 – Develop motor capability



Comparison to DDP096

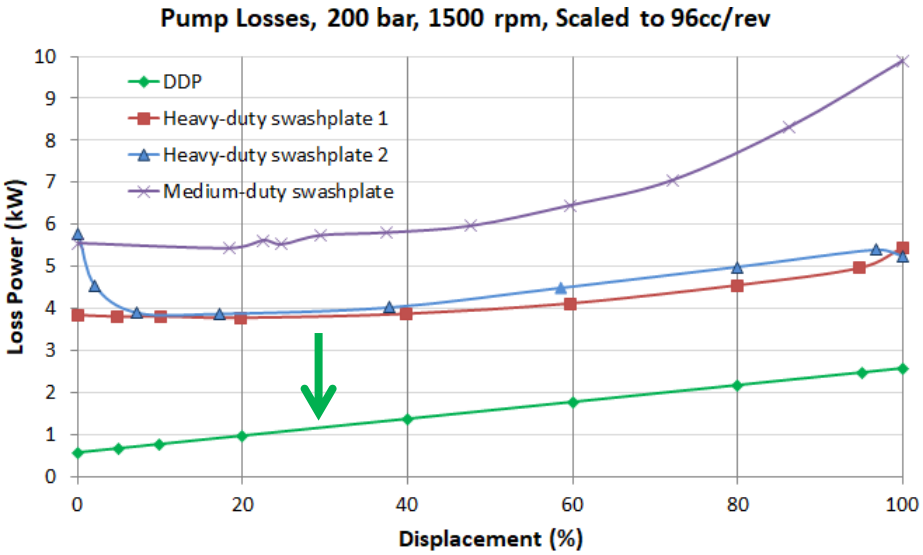
Better component efficiency

Efficiency:



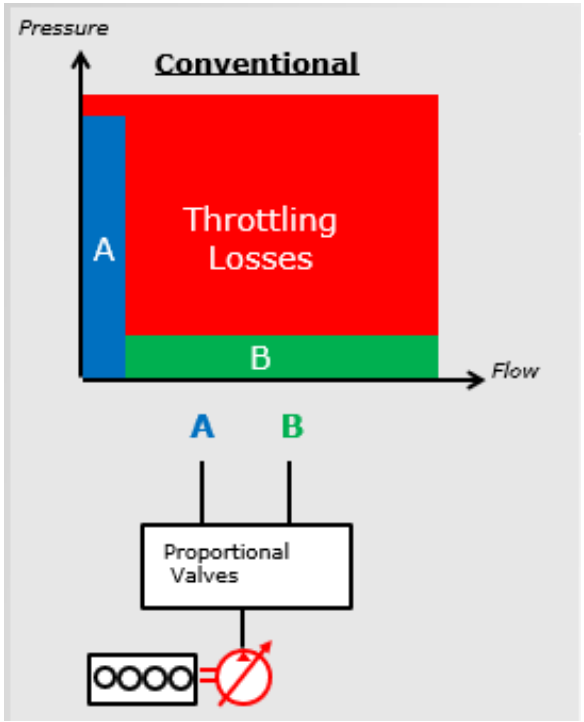
Unprecedented efficiency…
Similar to electric motors

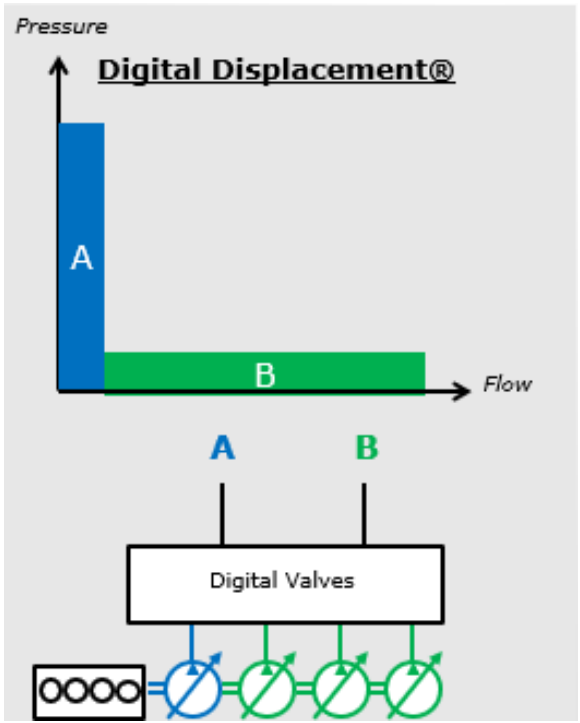
Losses:



1/3rd – 1/5th of the losses of analog variable pumps over a duty cycle

Reduced Valve Losses



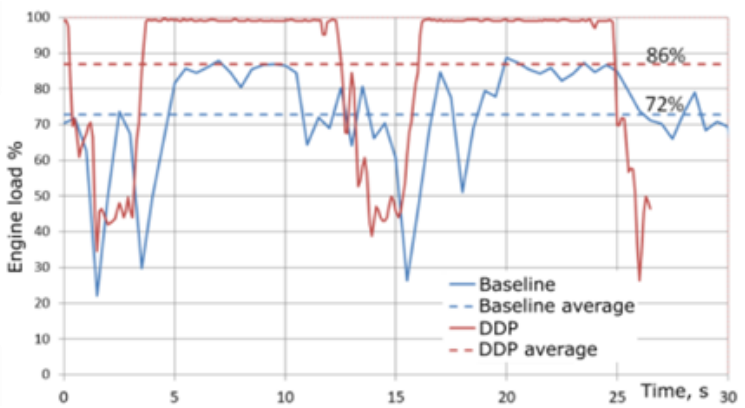


Completely new architectures are now possible.

Multiple outputs directly supply loads without throttling-reducing energy losses.

Controllability

- Engine related load control
  - Anti-stall
  - Dynamic torque allocation
  - Engine torque maximisation
- Increased productivity
- New system architectures
  - Multi-service
  - Direct load control
  - Mixed control functions

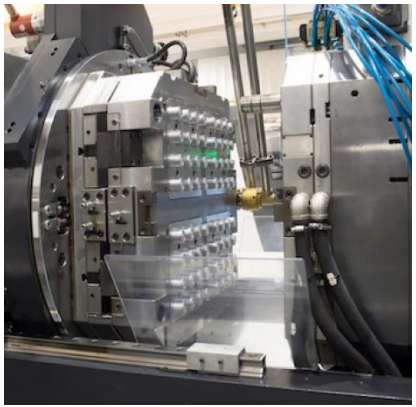


Where does DDP come into play?

Off-Highway and Industrial markets

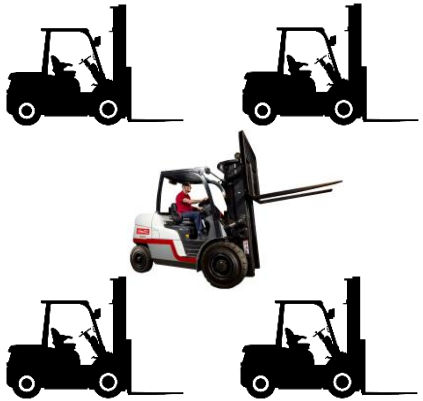
Energy-critical

Productivity-driven



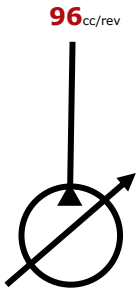
Highly **dynamic**

Need to **differentiate**



‘Normal Pump’

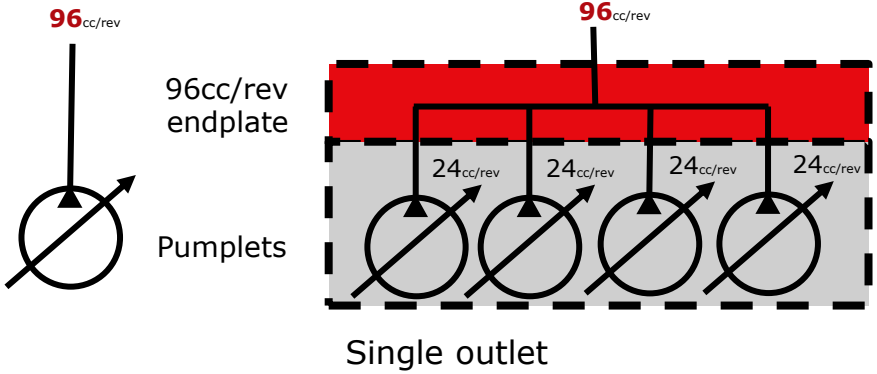
One outlet



96cc/rev
Single Outlet

‘Normal Pump’

One outlet

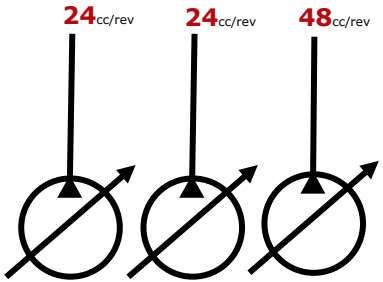


Single outlet

96cc/rev
Single Outlet

Digital Displacement Pump

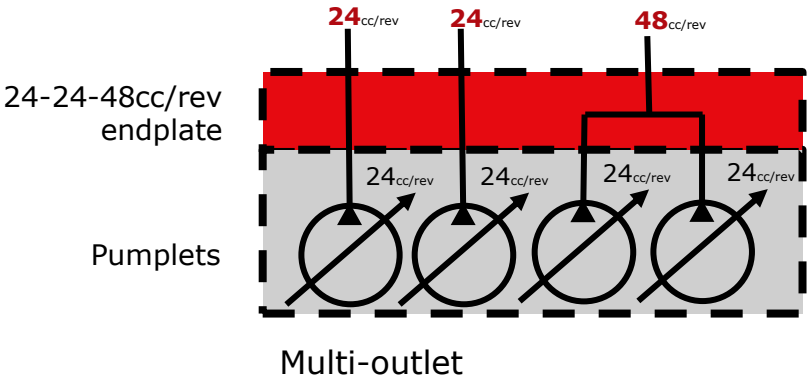
Multiple outlets



96cc/rev
Multiple Outlet

Digital Displacement Pump

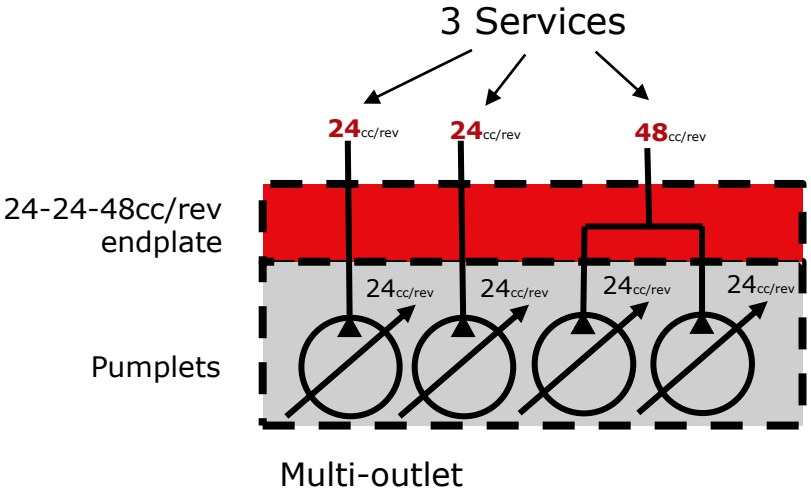
Multiple outlets



Multi-outlet

96cc/rev
Multiple Outlet

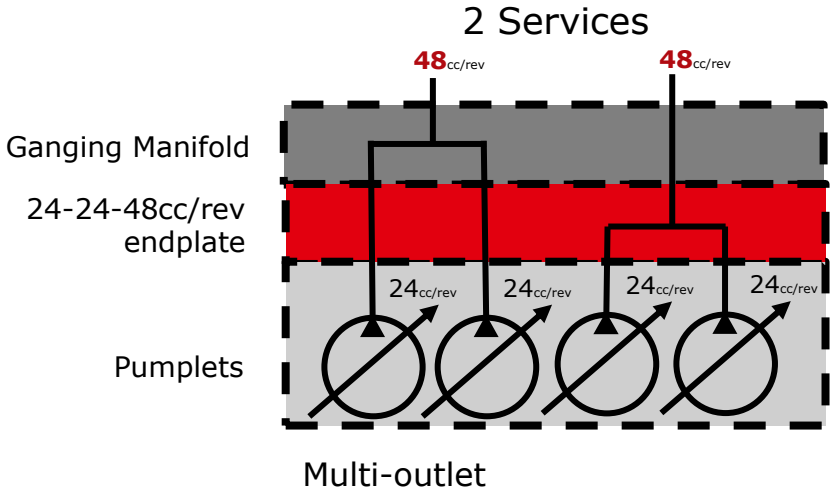
DDP – **Services**



96cc/rev
Multiple Outlet

Services are what the customer controls

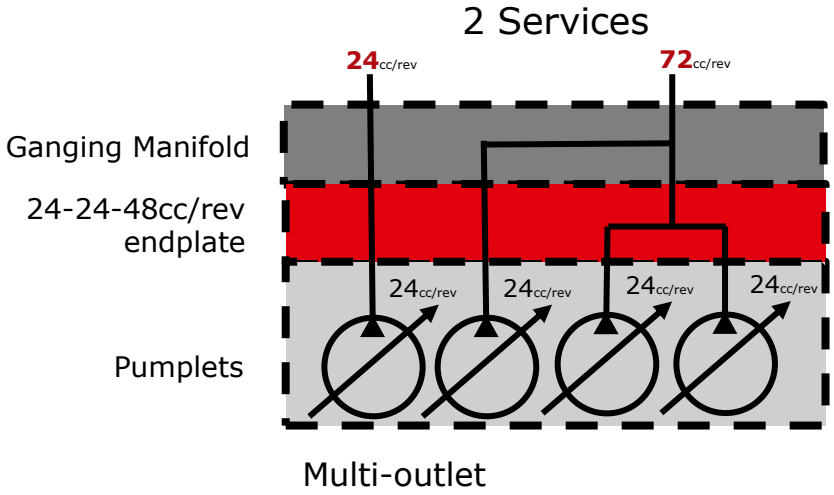
DDP – **Services**



96cc/rev
Multiple Outlet

Services are what the customer controls

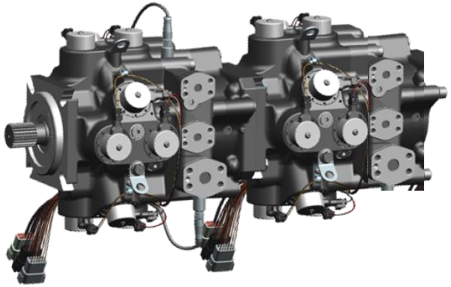
DDP – **Services**

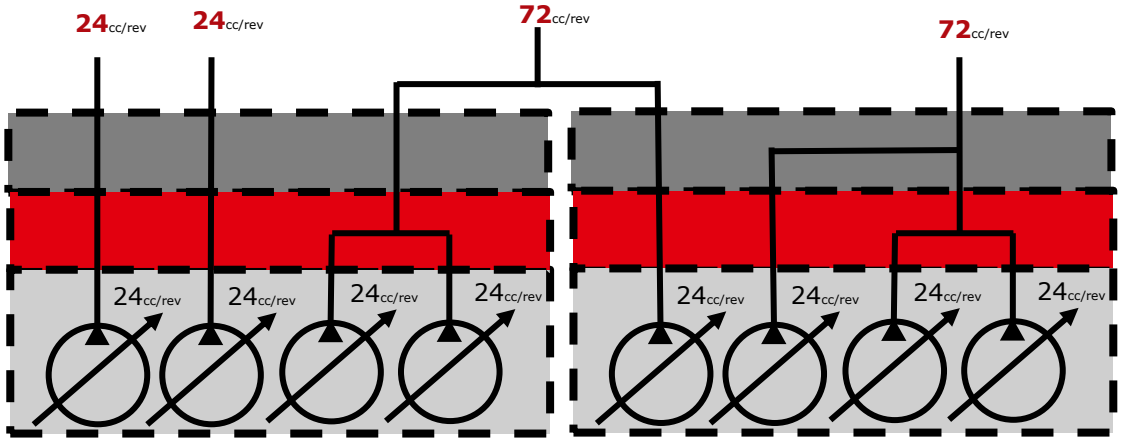


96cc/rev
Multiple Outlet

Services are what the customer controls

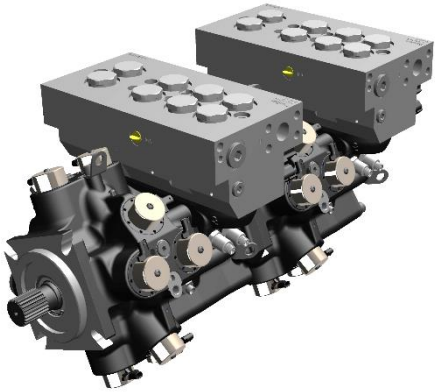
DDP – **How far can we take this?**

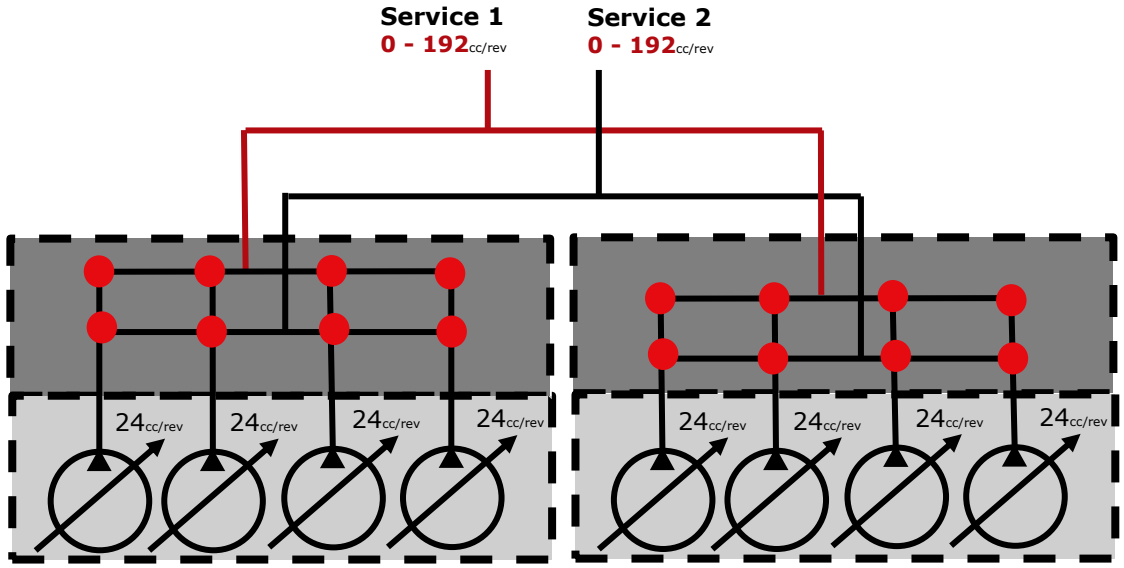




Tandem Multi-outlet

DDP – **We can go even further?**





Tandem Multi-outlet

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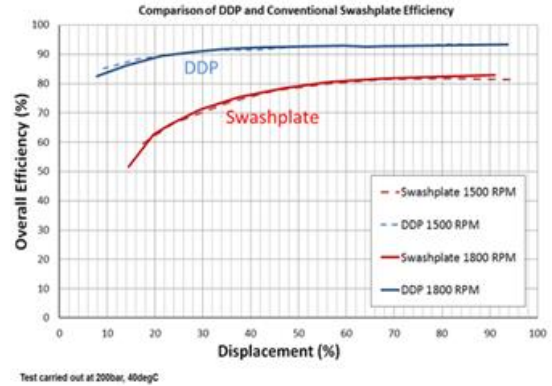
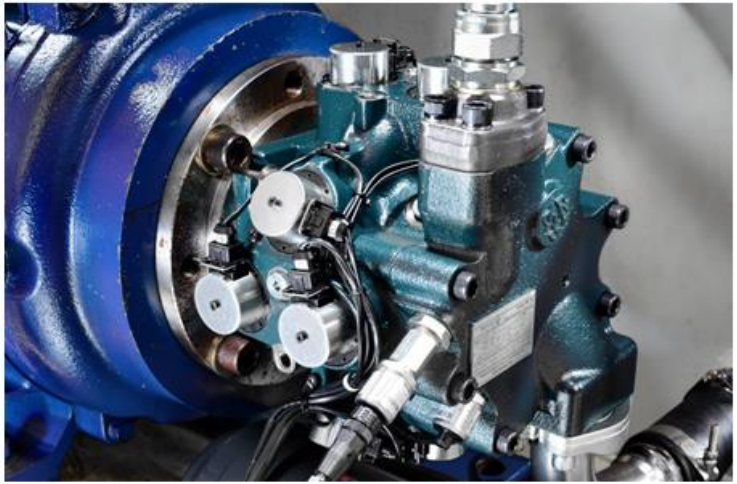
Application Examples

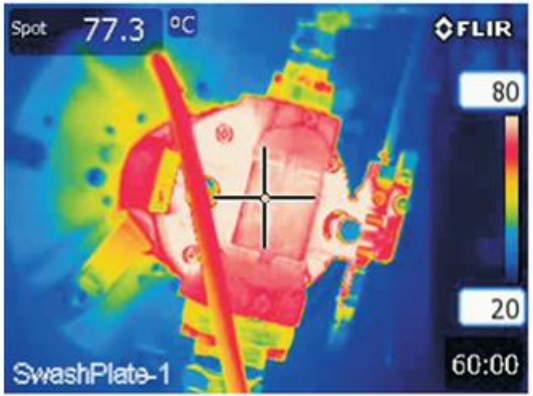
Example application:
Industrial Hydraulic Power Unit

- **Low energy consumption** for spinning reserve pumps
- **Simple internal offloading** during motor start-up
- **Reduced heat rejection** from pump losses
- High bandwidth control **response**

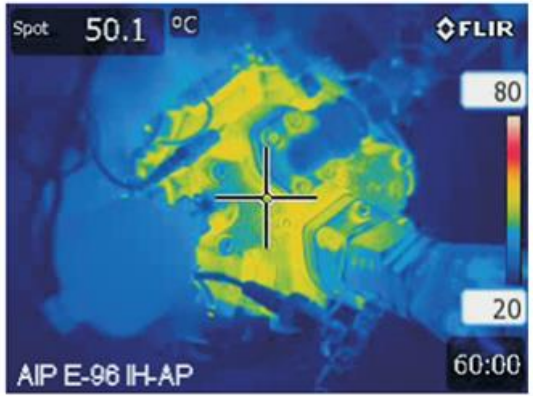




Pressurised idle losses at 200 bar



Axial piston pumps
6kW of losses



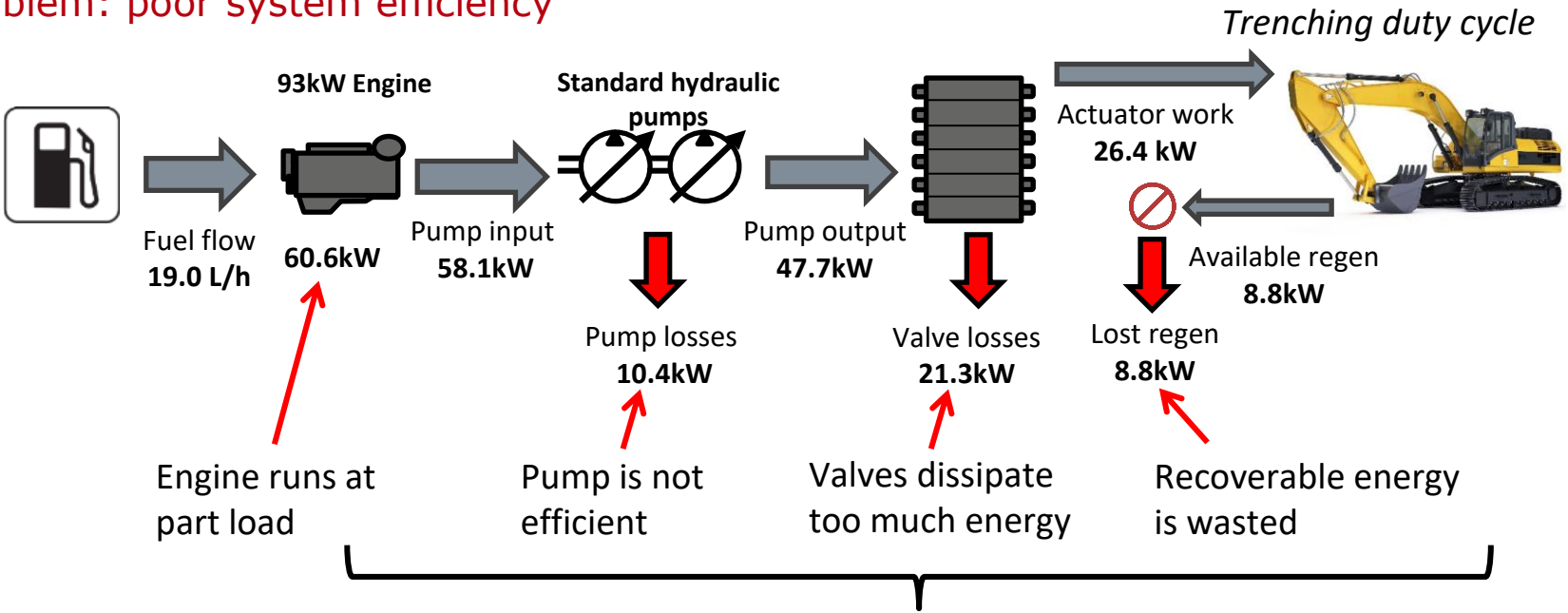
Digital Displacement® Pumps
0.6 kW of losses

Digital Displacement Pumps
Power Generation Use Case

- Remote mounting of generator
  - Hydraulicly driven
  - Lower cost synchronous generator
  - Less power electronics
- Constant flow with changing engine RPM
  - 30ms response time
- Remove generator weight from engine aux drive
  - Removes supports & brackets
- Free up space in engine compartment
  - Ease maintenance access
  - Makes room for other hardware

A Potential for Change

Problem: poor system efficiency



Net work delivered = **17.6kW**

Pump input power = **58.1kW**

Overall efficiency of hydraulic system is 30%

Unrivalled Efficiency

Made possible by Digital Displacement system architectures

System Architecture	What is it?	Benefits	Energy savings
SA1	Pump swap	• Reduced pump losses • Higher productivity	21% (measured)
SA2	Optimized system	• Reduced valve losses	32% (measured)
SA3	New system architecture	• Minimised throttling losses • Energy recovery • Engine load levelling	+50% (simulation)

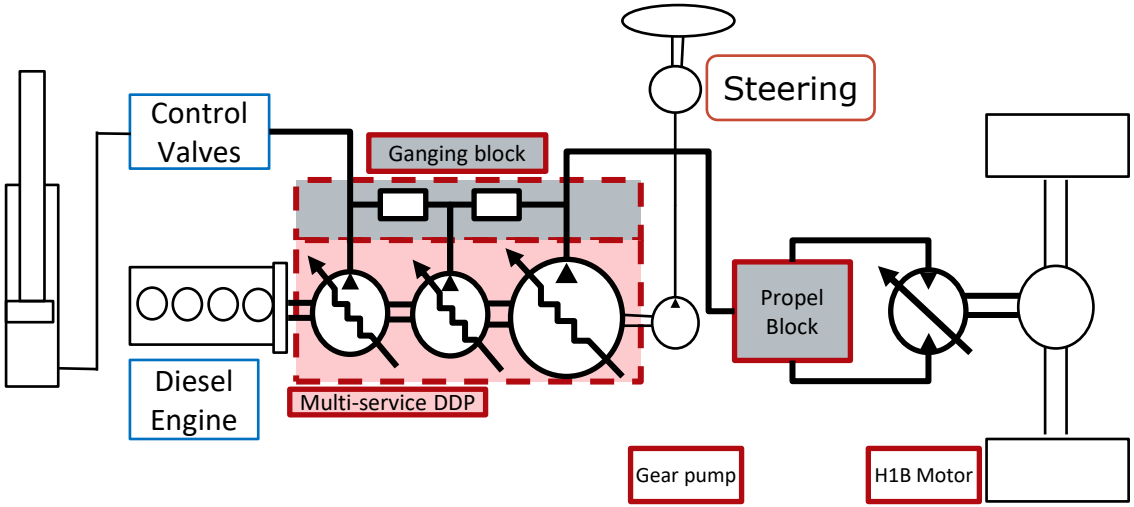
Fuel Efficiency: Material Handling

- 4 to 10 ton Fork Lift Trucks
- 40% Fuel Savings
- No loss of productivity
- Easy to customize drive behavior
- Demonstrated ability to reduce engine size

40%

Reduction in fuel consumption

Forklift Work Function + Propel

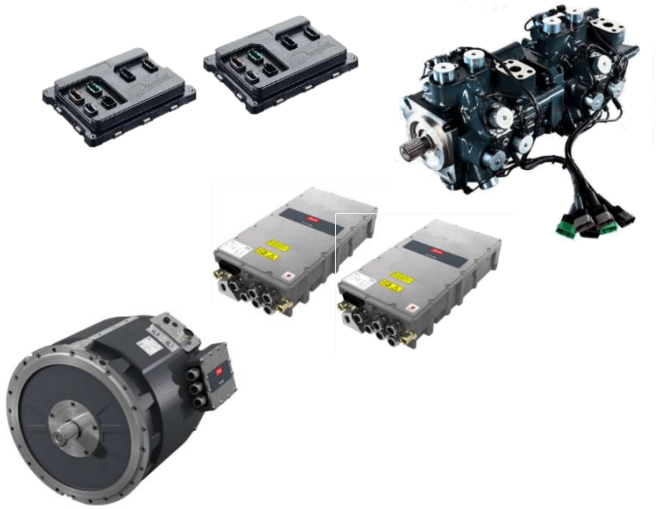


40%

Fuel Saving
(compared to torque converter)

Machine Electrification

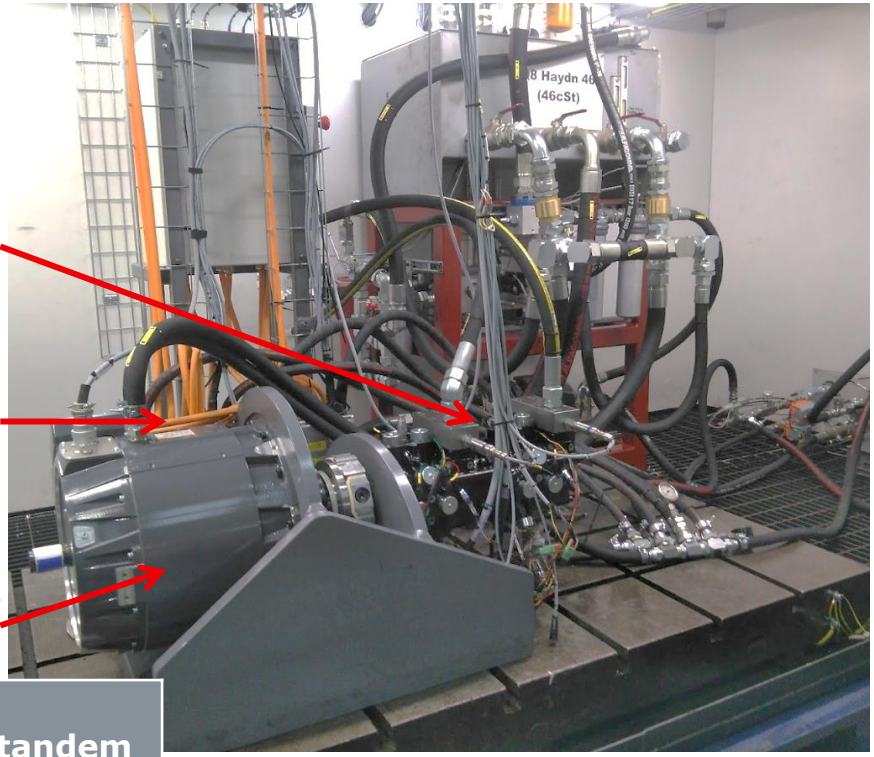
Combined DDP + Editron rig



DDP
E-dyn96 tandem
6 output

Editron Inverters
EC-C1200-450

Editron Motor
EM-PMI375-T800



	Editron PMI375-800+Inverter	DDP E-dyn96 tandem
Mass:	210kg + 30kg	110kg + 6kg
Cont. torque:	1000Nm	1192Nm
Cont. power@2500rpm	220kW	308kW (@420 bar)
Inertia:	0.63kgm^2	0.0024kgm^2

Machine Electrification

Combined DDP + Editron rig

87% overall

93.4%

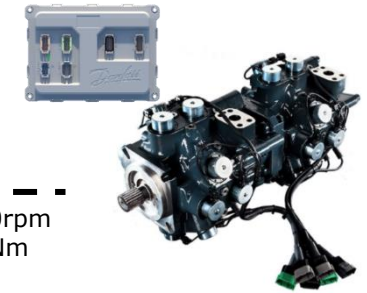
93.1%

DC Power

700V DC

AC

1500rpm
567Nm

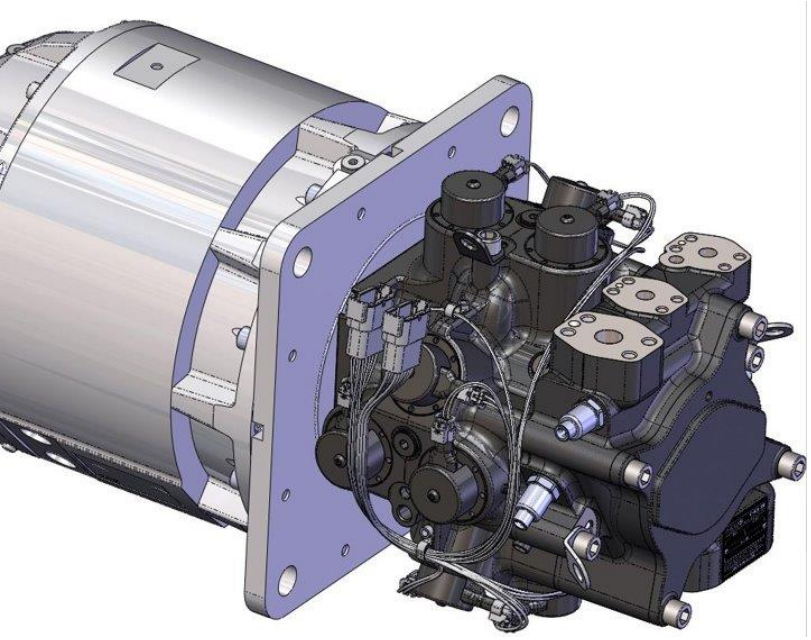


88kW
200 bar
265 l/min

Fluid Power

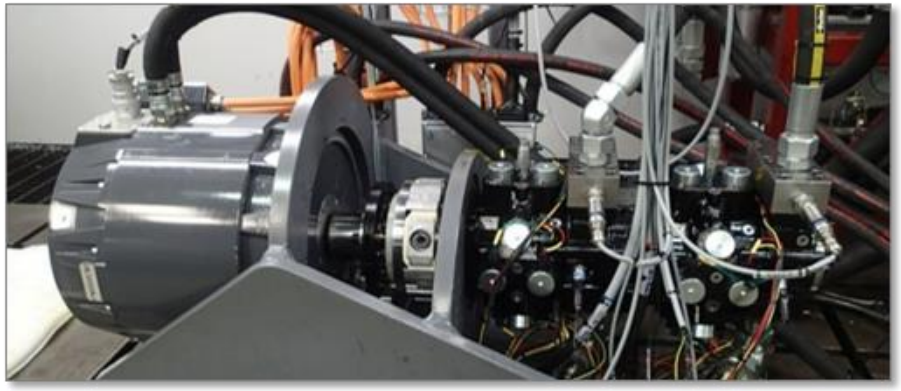
Machine Electrification

Combined DDP + Editron



20-50%

- Reduction of battery size
- Expansion of operating range



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Digital Displacement Benefits

DDP Benefits

Fuel / energy savings

- Fuel reduction or battery life increase
- Reaction time
  - Engine downsizing

Productivity improvement

System design possibilities

Component reduction / technology reduction

- Reduce system costs
- Propel / work function combination
- Integrated sensors
- Engine downsizing
- Battery reduction

Increased functionality

Safety

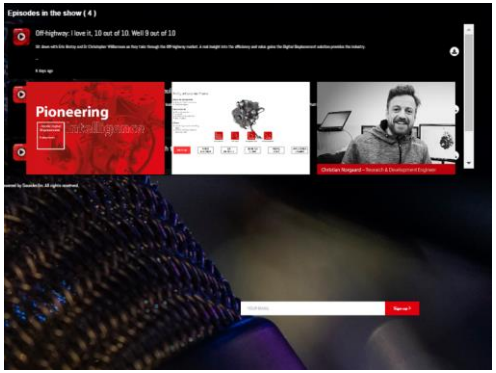
DDP Benefits

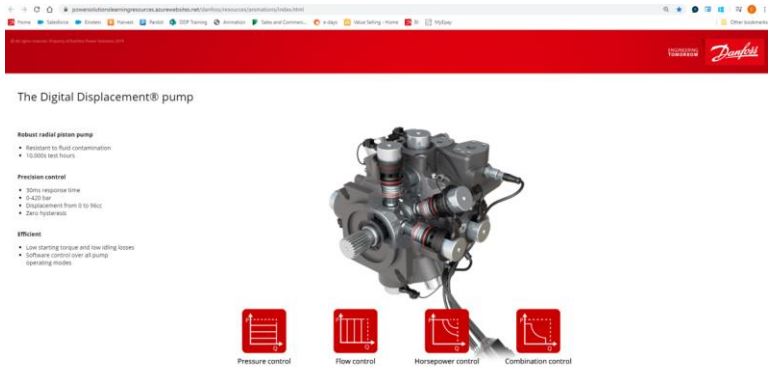
- **Consistent response regardless of speed, pressure, temperature**
  - No Hysteresis
  - Repeatability
  - Controllability

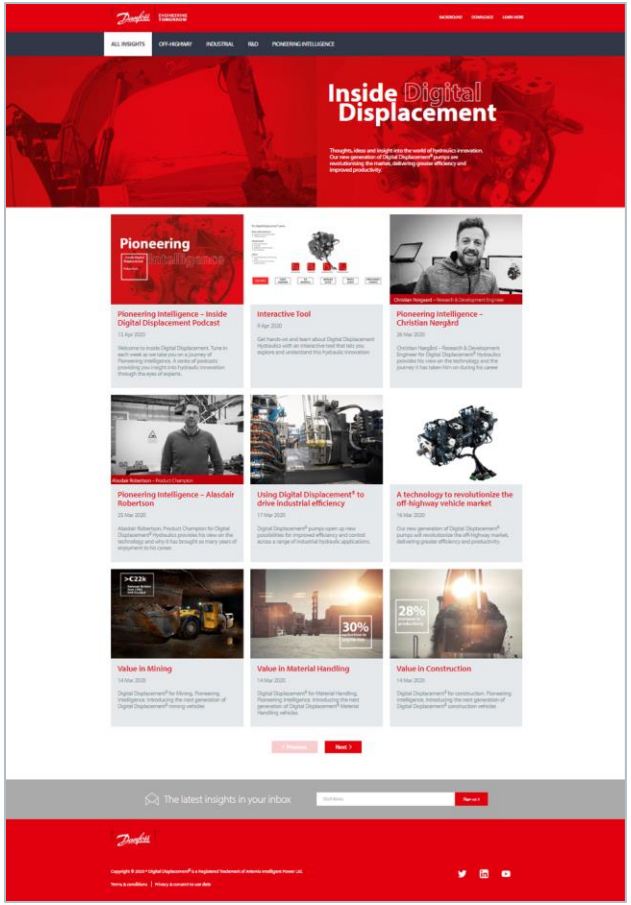
- **CAN J1939 interface allows for:**
  - Digital communication
  - Diagnostics
  - System feedback to CAN network
  - Fault detection
  - Telematics
  - IoT

- **Customization of pump control by software**
  - Electronic load sense
  - Pressure limiting
  - Command flow and/or mode
  - Operational modes

Resources







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