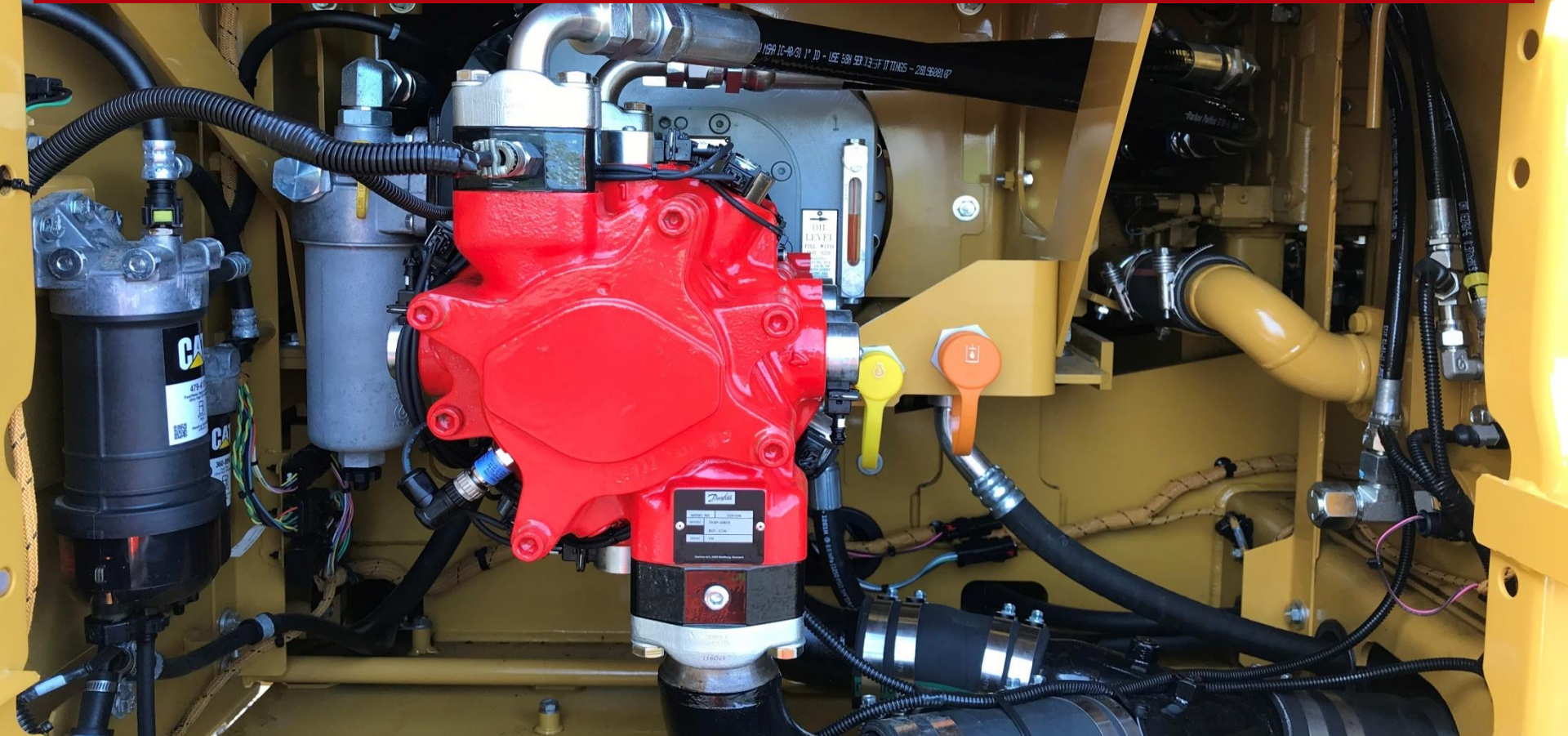


Danfoss Digital Displacement

ENGINEERING
TOMORROW

Danfoss

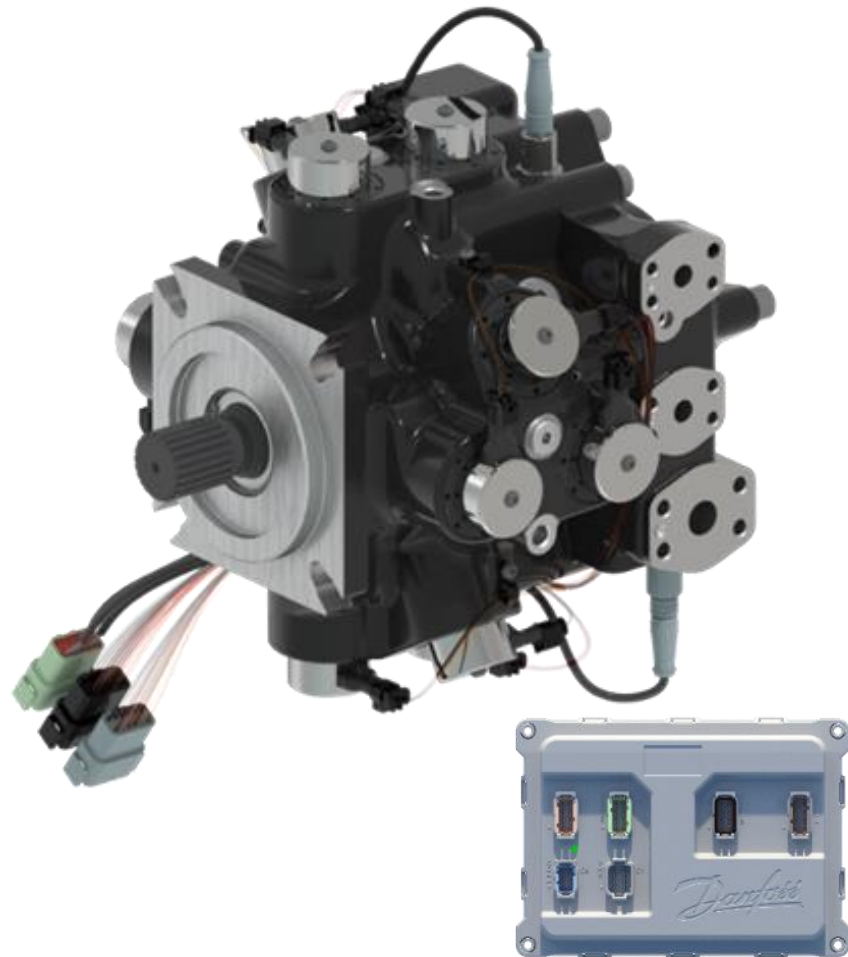


What is DDP?

Digital Displacement Pump

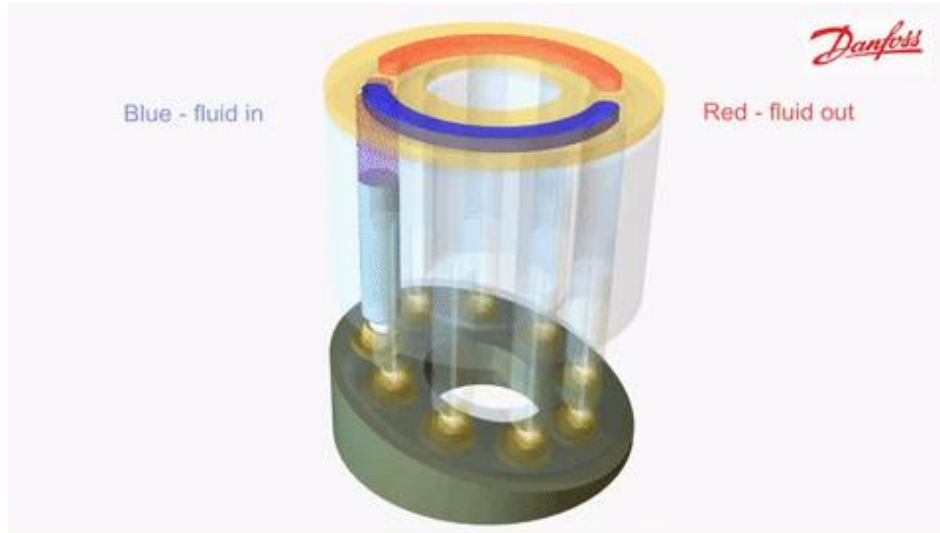
Overview

- 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

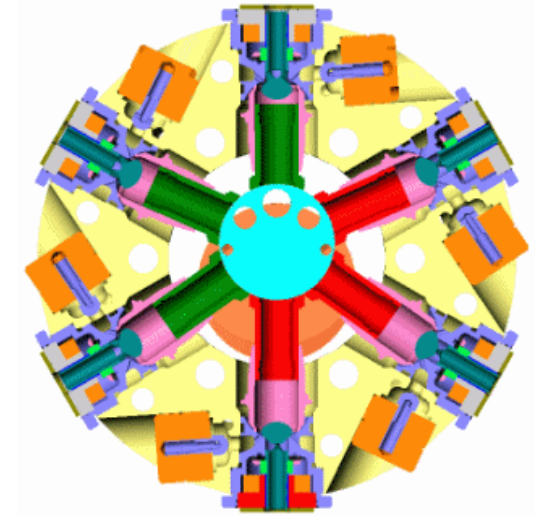


What is DDP?

Digital Displacement Pump

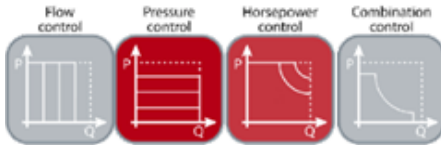
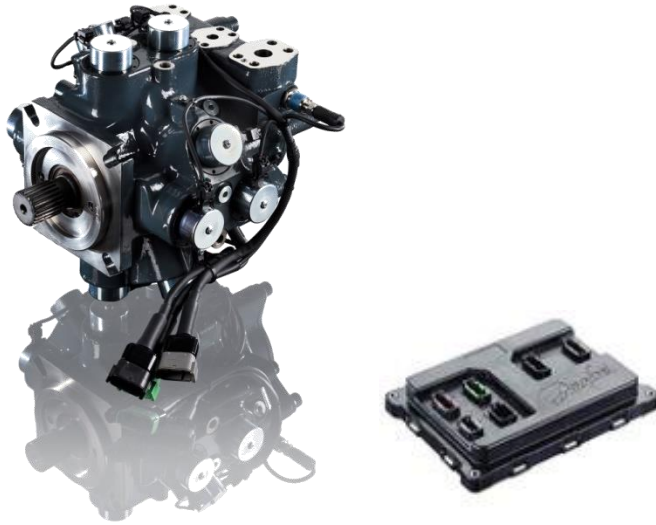


Axial Piston Pump



Digital Displacement Pump

DDP Features



Unique Features

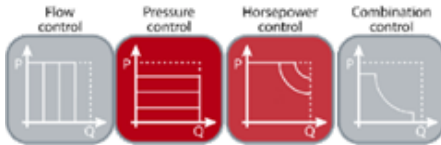
- Robotics-level control capability
 - Digital control of individual pistons
- Highest efficiency hydraulic pump available
- Fast and accurate response in 30 ms
- High efficiency – optimized radial design
 - 94% peak efficiency
 - >90% efficiency across a very broad range
- Very low idle losses
- Starts 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



**DPC12 Configuration**ENGINEERING TOMORROW

Valid Configuration

DANFOSS DPC12 GENERAL CONFIGURATION

Baudrate
The baudrate used by the DPC12. Requires a power cycle to take effect.
250K

Node Address
The CAN bus address used by the DPC12. Requires a power cycle to take effect. Make sure to press the Scan System and Replace Missing ECU buttons after power cycle for the connection to the DPC12.
250

Minimum Speed for Pumping
1700 rpm

Pressure Fault Limit
450 bar

Pumping Enable Source
CAN

Require DM13 Message
0

PARAM UPLOAD PARAM DOWNLOAD
REPLACE MISSING ECU REPLACE EXISTING ECU
SCAN SYSTEM

DANFOSS DPC12 QUICK MODE SELECT

Mode - Quick Select

DISPLACEMENT CONTROL
PRESSURE COMPENSATION
LOAD SENSING



DANFOSS DPC12 MANUAL MODE SELECT

Pumping Mode
Pressure SELECT

Pressure Ctrl Mode
Pressure Compensation SELECT

Pressure Reference Limit
420 bar

Pressure Reference Source
CAN

**DPC12 Errors**ENGINEERING TOMORROW

DANFOSS DPC12 ERRORS

Device State: **Fault** RESET COUNTERS

ERROR	SPN	FMI	STATUS	COUNT
Pressure sensor signal invalid, service 1	S20960	11	●	<input type="checkbox"/>
Pressure too high, service 1	S20960	0	●	<input type="checkbox"/>
Pressure sensor signal invalid, service 2	S20960	11	●	<input type="checkbox"/>
Pressure too high, service 2	S20960	0	●	<input type="checkbox"/>
Control U.S. pressure sensor signal invalid, service 1	S20960	11	●	<input type="checkbox"/>
Shaft position sensor signal invalid	S20975	2	●	<input type="checkbox"/>
Shaft speed below limit	S20975	1	●	<input type="checkbox"/>
Shaft speed above limit	S20975	0	●	<input type="checkbox"/>
Reverse shaft direction	S20975	6	●	<input type="checkbox"/>
Pump temperature below limit	1636	17	●	<input type="checkbox"/>
Shaft speed above limit	S20975	11	●	<input type="checkbox"/>

Source: Danfoss Internal Data

KEY

- No error
- Source or critical error
- Power by power cycle only
- Warning
- Near to (2000 times) or power cycle
- Info
- No fault needed, but might enable purging



What is our Current offering

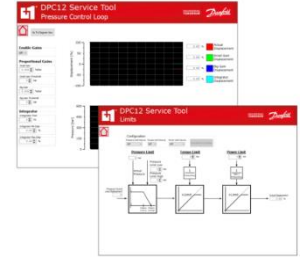
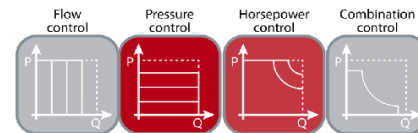
'Single'



'Multi'



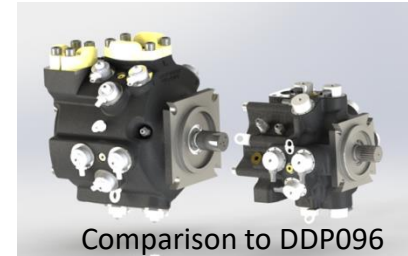
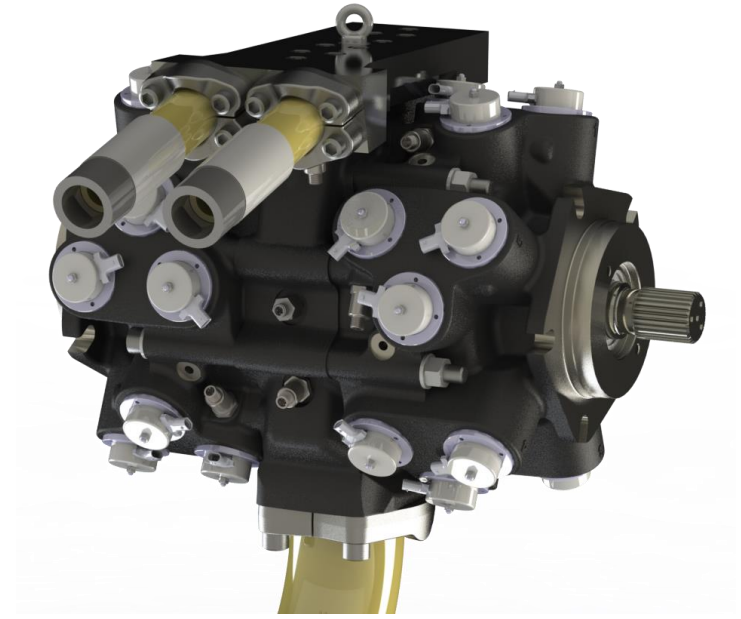
'Tandem'



Future Product Direction

Modular DDP – **DDP1X0**

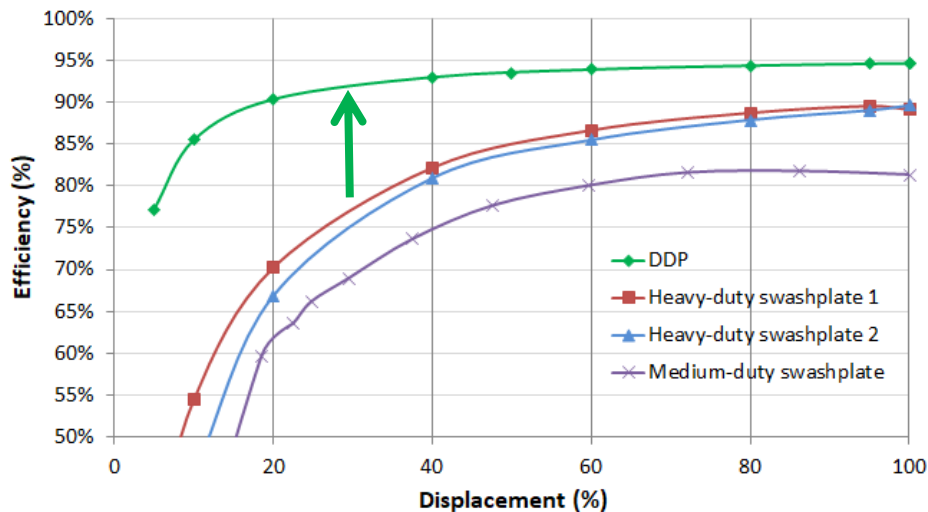
- Modularity at a piston and valve level
- Broad range of displacements
 - (2x) 120 to 180 cc/rev
- Excavator as initial target market
 - 1 - Start with pumps
 - 2 – Develop multi-service
 - 3 – Develop motor capability



Better component efficiency

Efficiency:

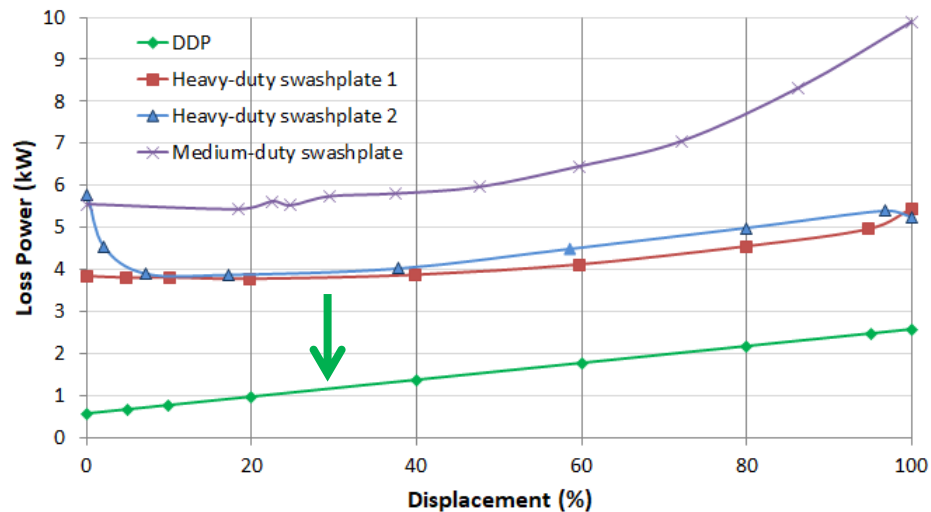
Pump Efficiency, 200 bar, 1500 rpm



Unprecedented efficiency...
Similar to electric motors

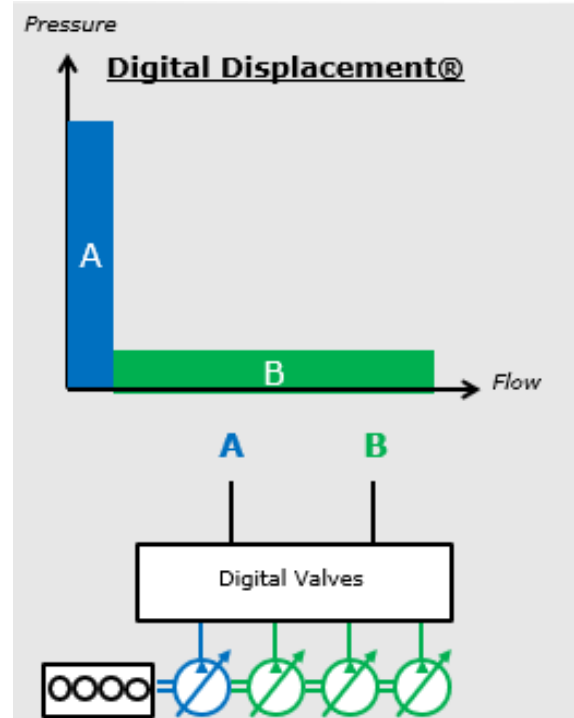
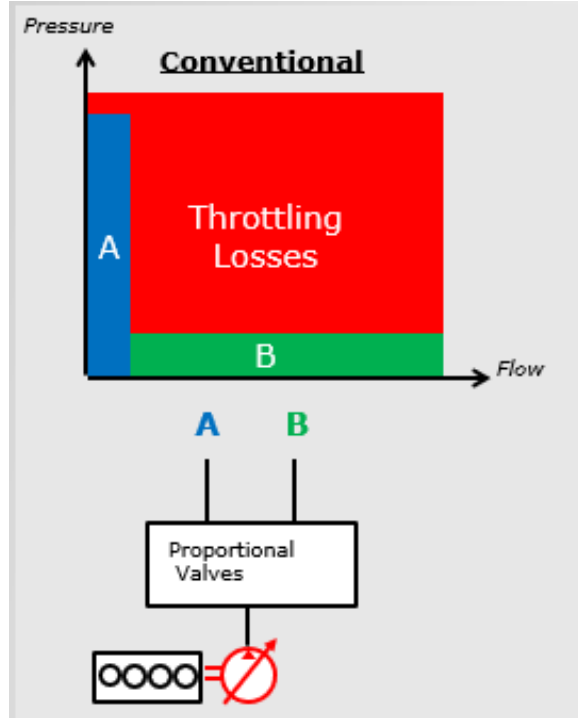
Losses:

Pump Losses, 200 bar, 1500 rpm, Scaled to 96cc/rev



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

Reduced Valve Losses

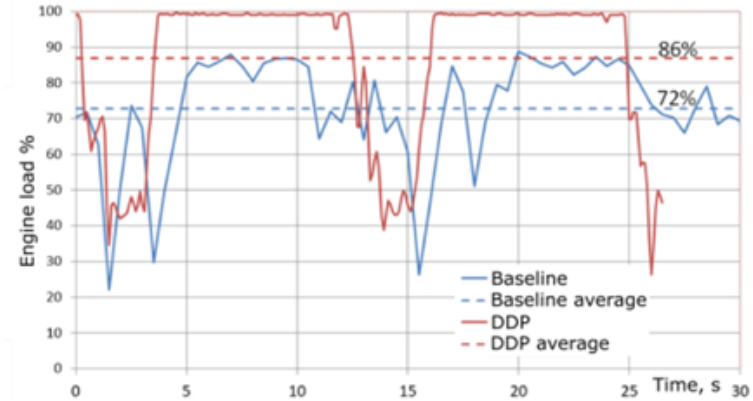


Completely new architectures are now possible.

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



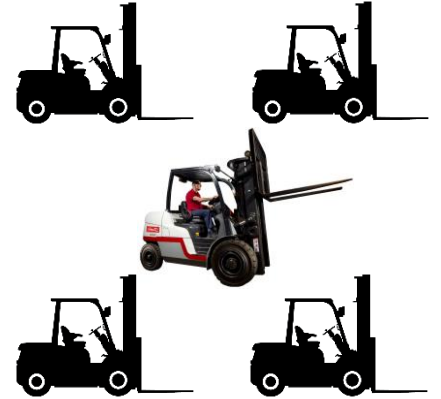
Energy-critical

Productivity-driven



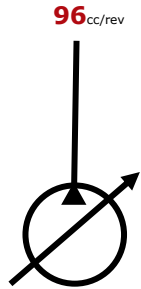
Highly **dynamic**

Need to **differentiate**



'Normal Pump'

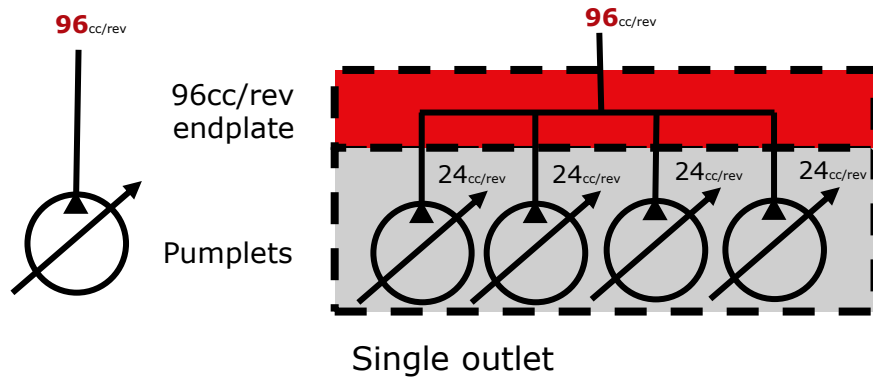
One outlet



96cc/rev
Single Outlet

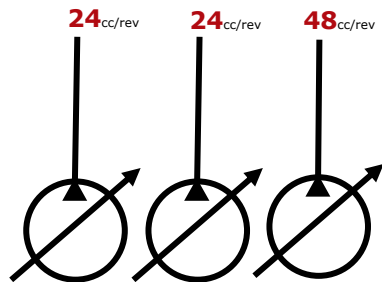
'Normal Pump'

One outlet



Digital Displacement Pump

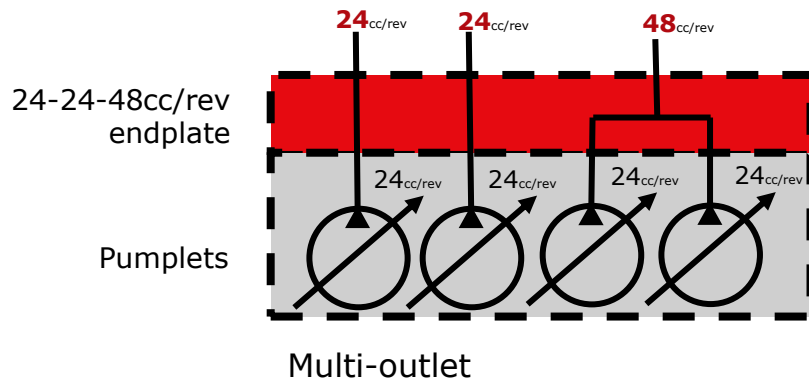
Multiple outlets



96cc/rev
Multiple Outlet

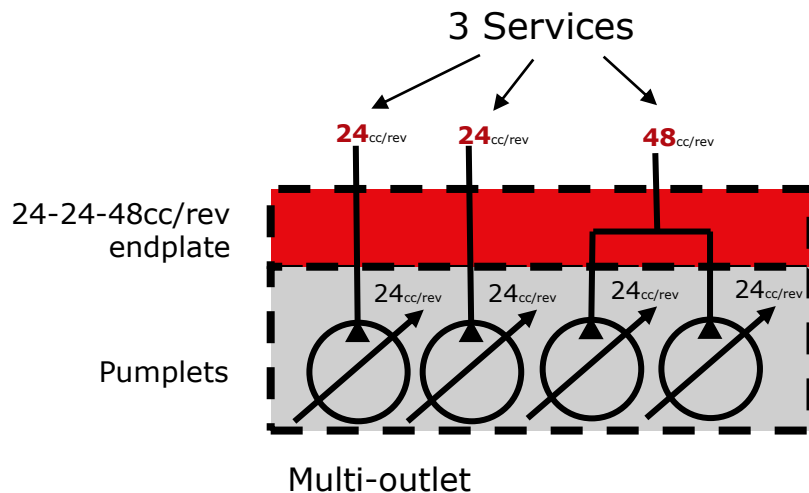
Digital Displacement Pump

Multiple outlets



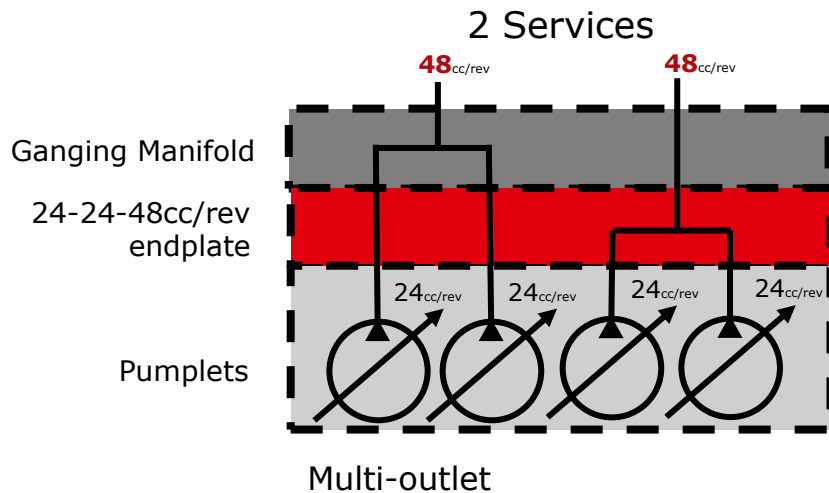
96cc/rev
Multiple Outlet

DDP – Services



Services are what the customer controls

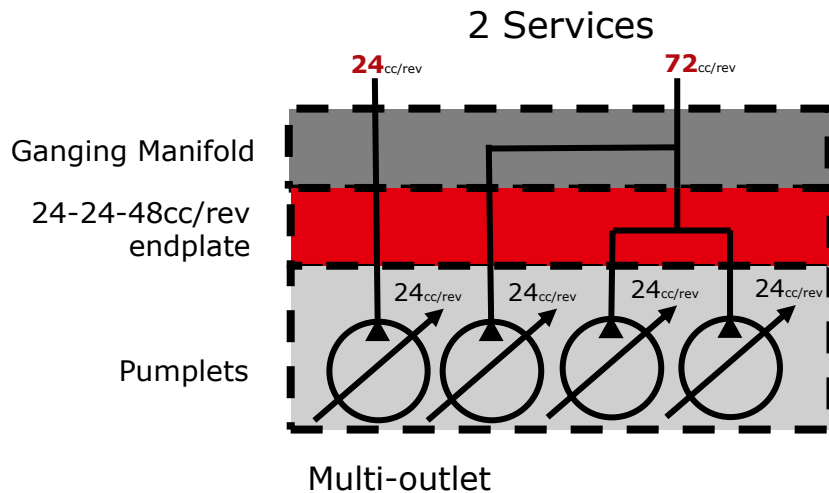
DDP – Services



96cc/rev
Multiple Outlet

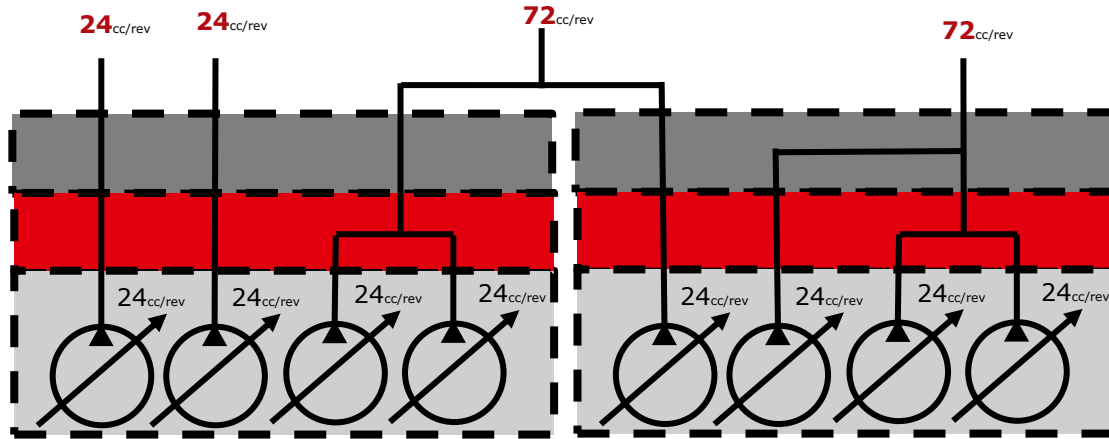
Services are what the customer controls

DDP – Services

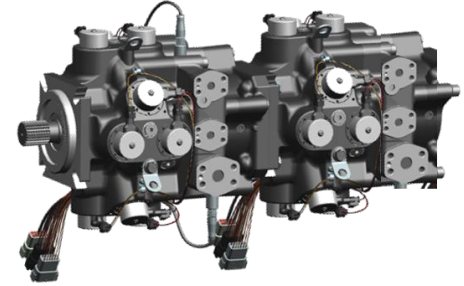


Services are what the customer controls

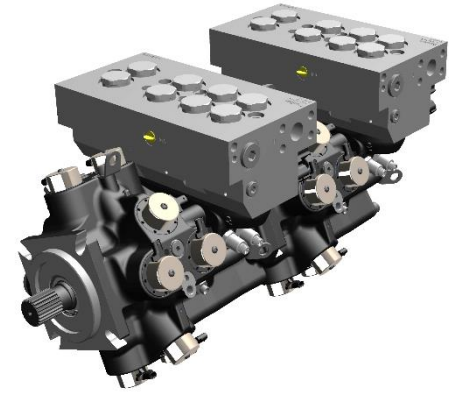
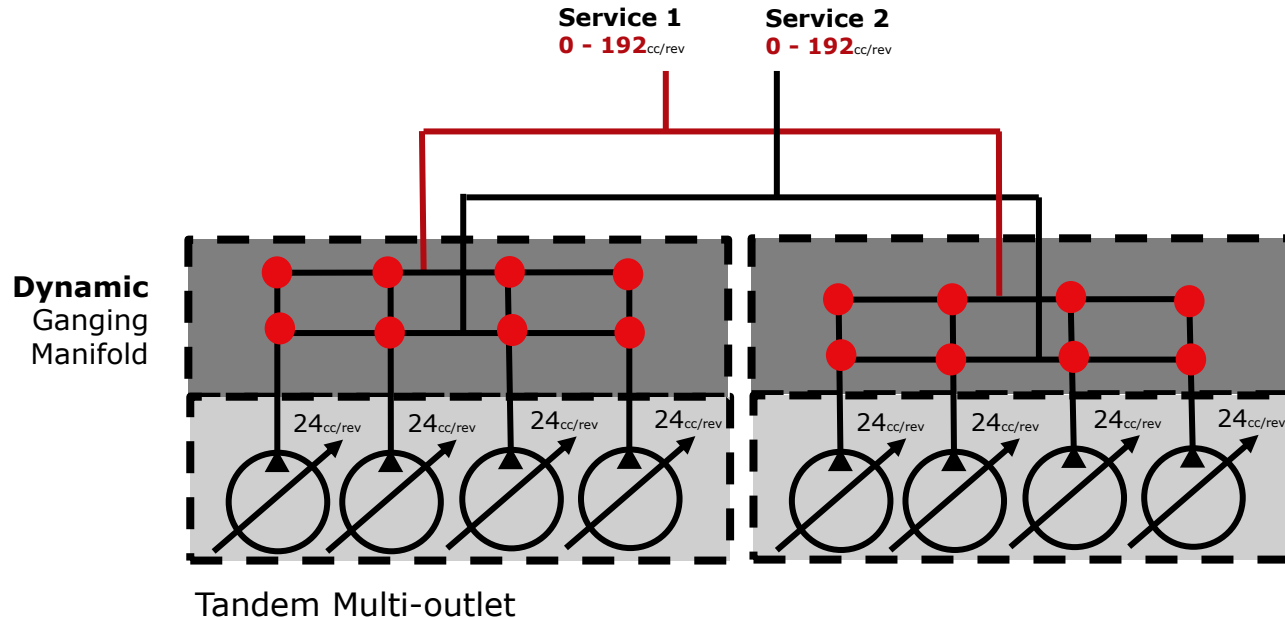
DDP – How far can we take this?



Tandem Multi-outlet



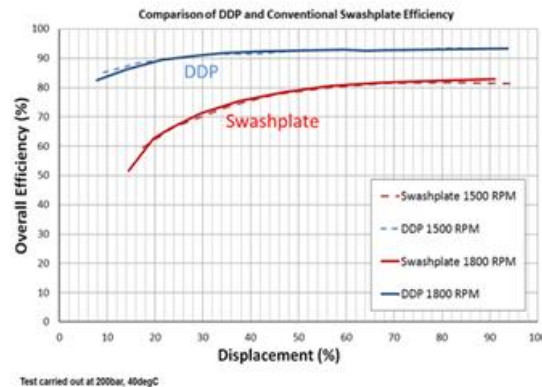
DDP – We can go even further?



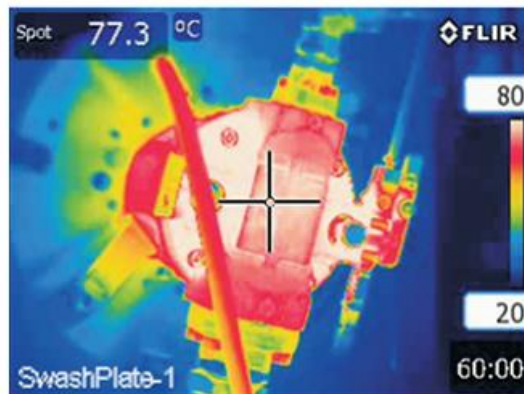
Application Examples

Example application: Industrial Hydraulic Power Unit

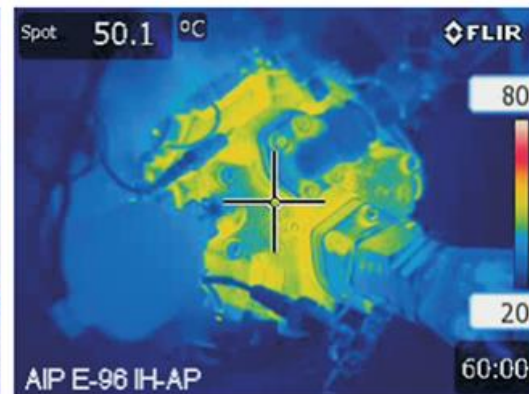
- **Low energy consumption** for spinning reserve pumps
- **Simple internal offloading** during motor start-up
- **Reduced heat rejection** from pump losses
- High bandwidth control **response**



Pressurised idle losses at 200 bar



Axial piston pumps
6kW of losses



Digital Displacement® Pumps
0.6 kW of losses

Digital Displacement Pumps

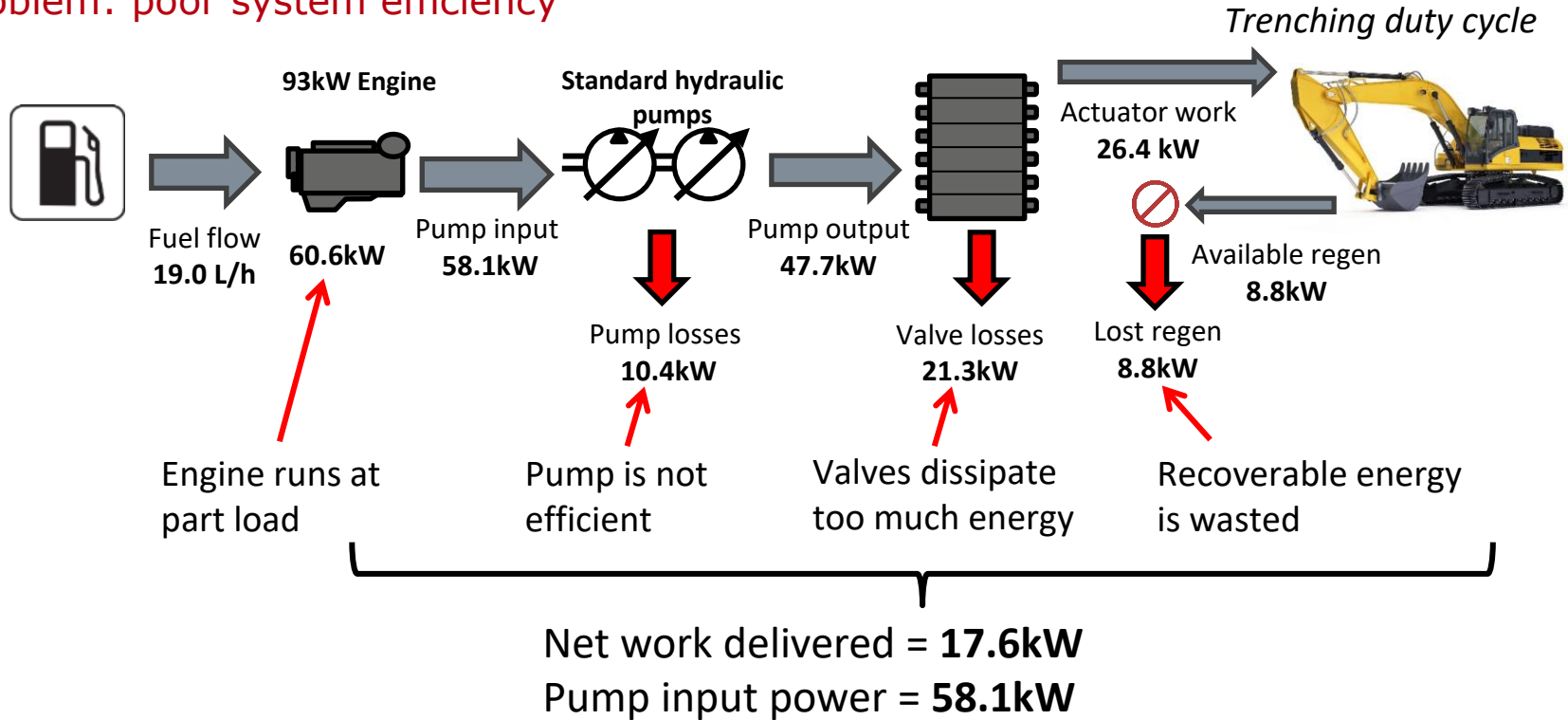
Power Generation Use Case

- Remote mounting of generator
 - Hydraulically 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



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	<ul style="list-style-type: none">Reduced pump lossesHigher productivity	21% (measured)
SA2	Optimized system	<ul style="list-style-type: none">Reduced valve losses	32% (measured)
SA3	New system architecture	<ul style="list-style-type: none">Minimised throttling lossesEnergy recoveryEngine load levelling	+50% (simulation)

Fuel Efficiency: Material Handling

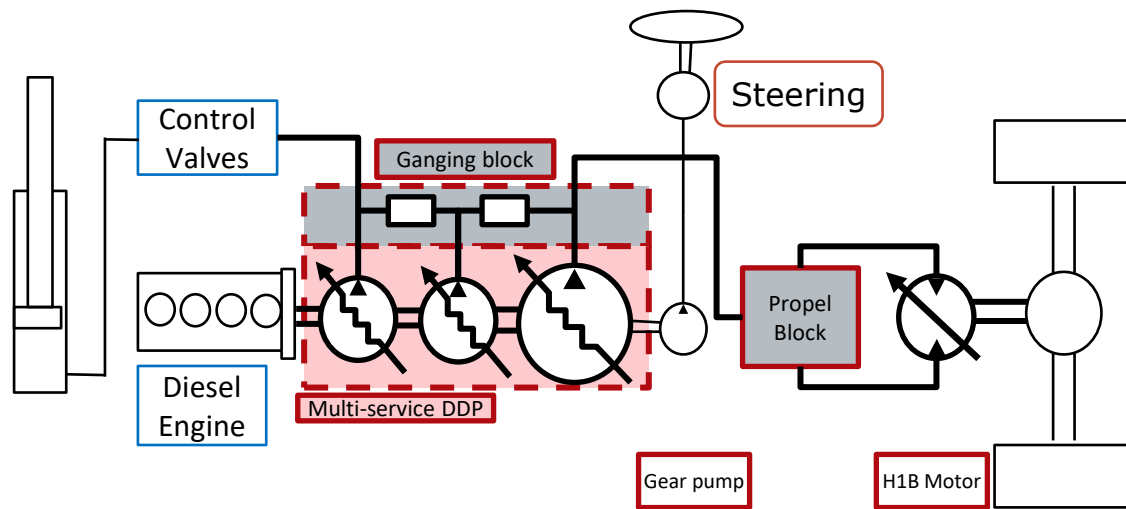
- 4 to 10 ton Fork Lift Trucks
- 40% Fuel Savings
- No loss of productivity
- Easy to customize drive behavior
- Demonstrated ability to reduce engine size

40%

Reduction
in fuel
consumption



Forklift Work Function + Propel

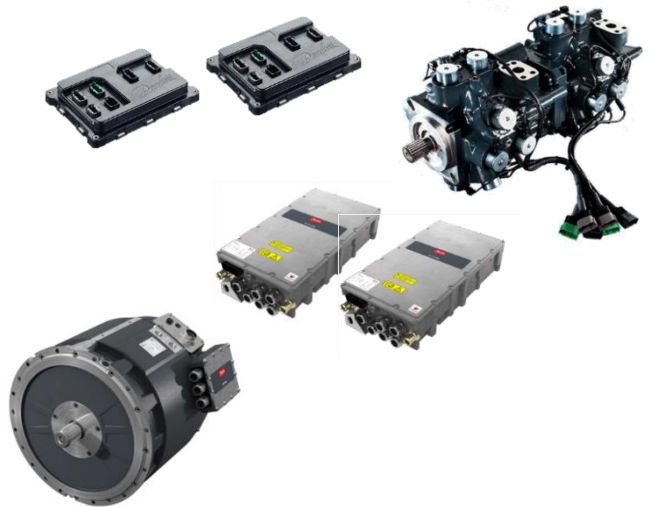


40%

Fuel Saving
(compared to
torque converter)

Machine Electrification

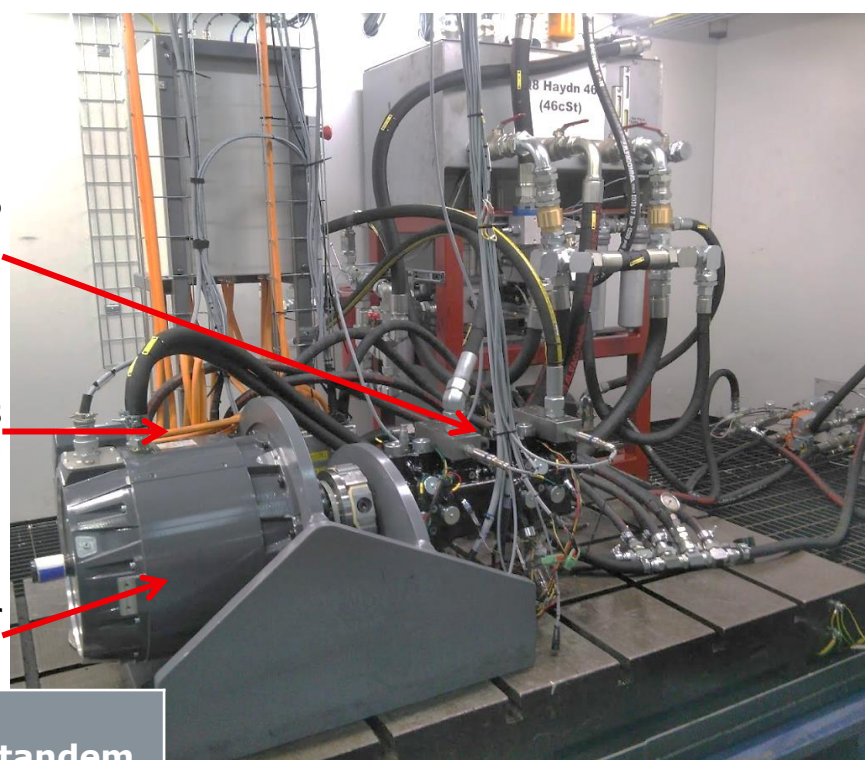
Combined DDP + Editron rig



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

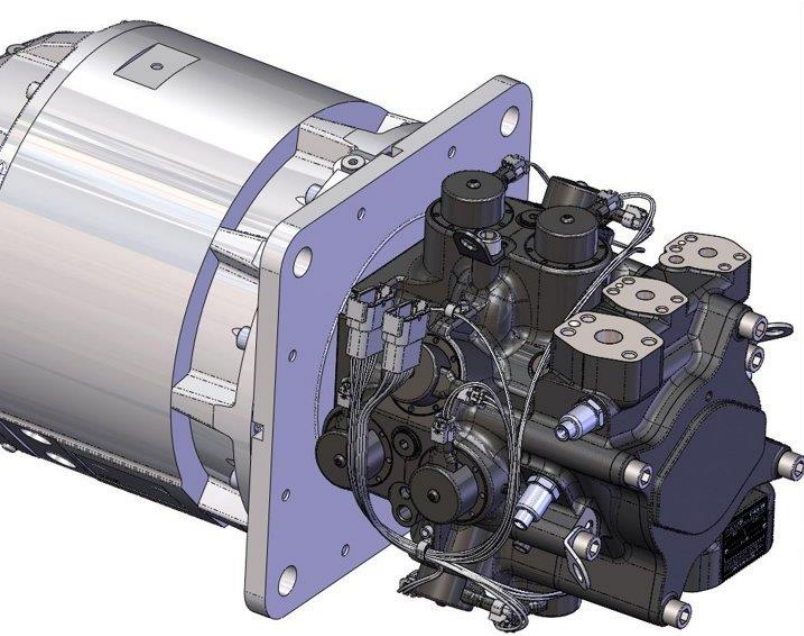


88kW
200 bar
265 l/min

Fluid
Power

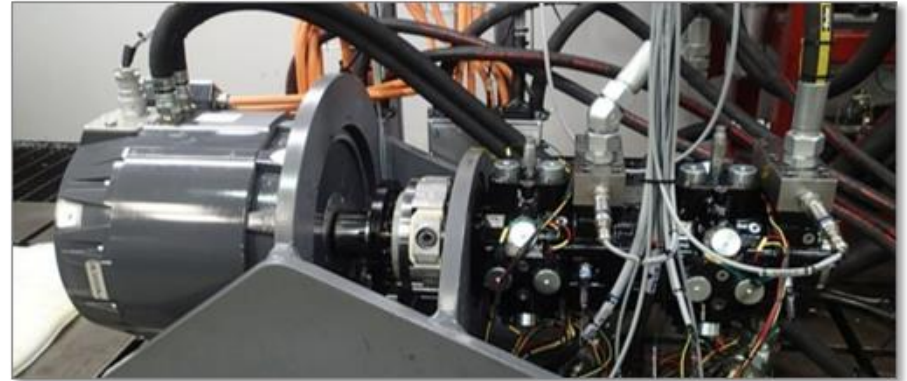
Machine Electrification

Combined DDP + Editron



20-50%

- Reduction of battery size
- Expansion of operating range



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

Pioneering Intelligence – Christian Nørgård

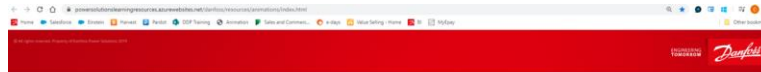
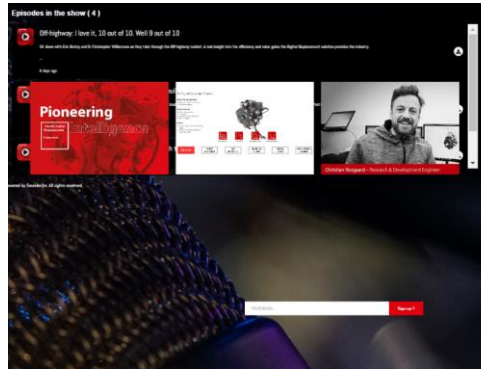
Since his time at Aalborg University in Denmark, Christian has been deeply involved with ground-breaking Digital Displacement® pump technology.

Like many, he has worked with Christian has the single-minded aim of transforming the entire hydraulic market for a better world.

It is his Pioneering Intelligence that has contributed to a machine that offers improved system efficiency, enhanced control, reduction in energy consumption and paving the way for a brighter, digital, sustainable future.



Christian Nørgård – Research & Development Engineer



The Digital Displacement® pump

Robust radial piston pump

- Resistant to fluid contamination
- 10,000 hrs. test hours

Precision control

- 30ms response time
- 6-42 bar
- Displacement from 0 to 36cc
- Zero leakage

Efficient

- Low starting torque and low idling losses
- Software control over all pump operating modes



Pressure control



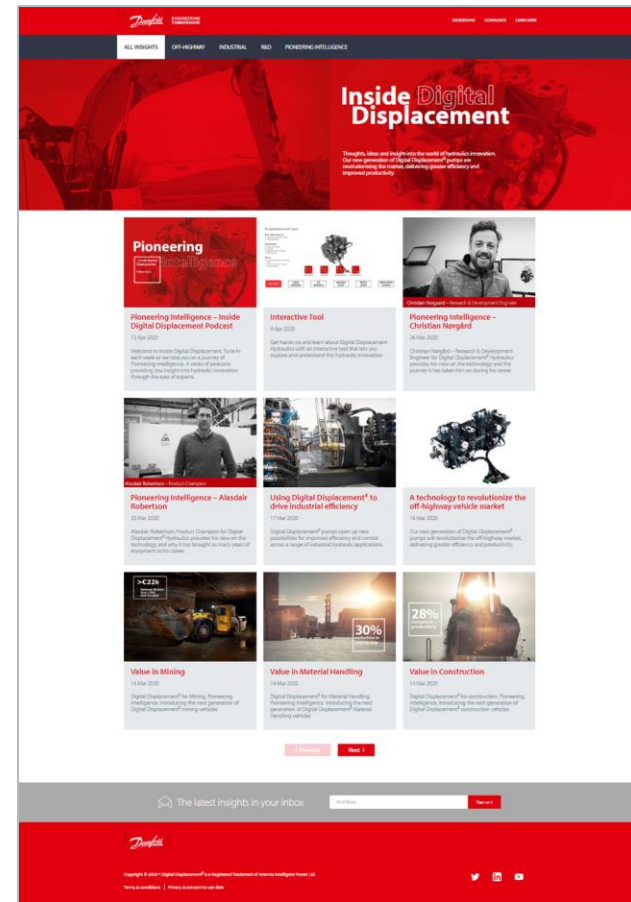
Flow control



Horsepower control



Combination control



<https://powersolutionslearningresources.azurewebsites.net/danfoss/resources/animations/index.html>

www.digitaldisplacement.com



ENGINEERING
TOMORROW