Pierburg Pump Technology

Electrical Waterpumps

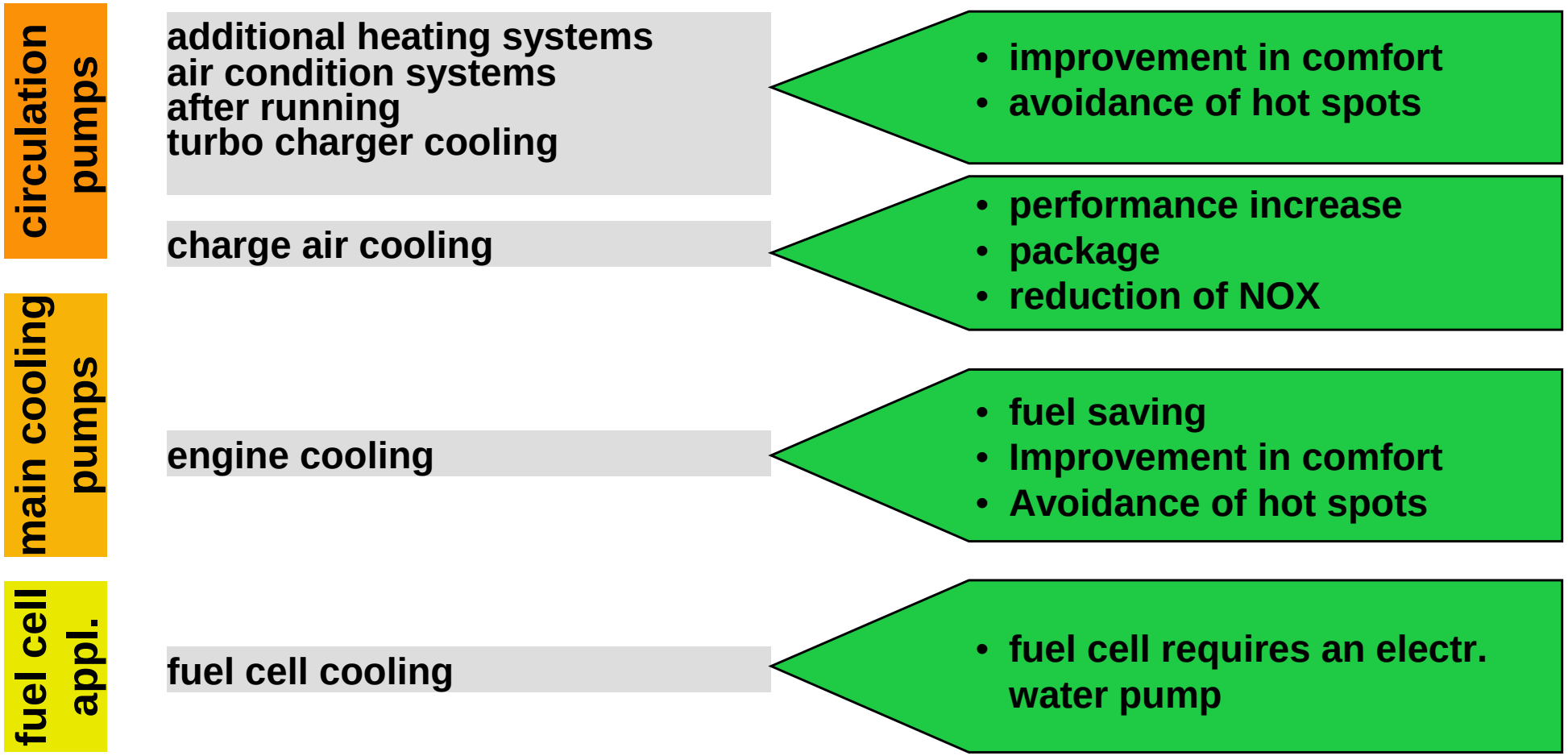
Dormagen, 04. März 2009

MOTOR SERVICE

PIERBURG PUMP TECHNOLOGY

Electrical cooling pumps

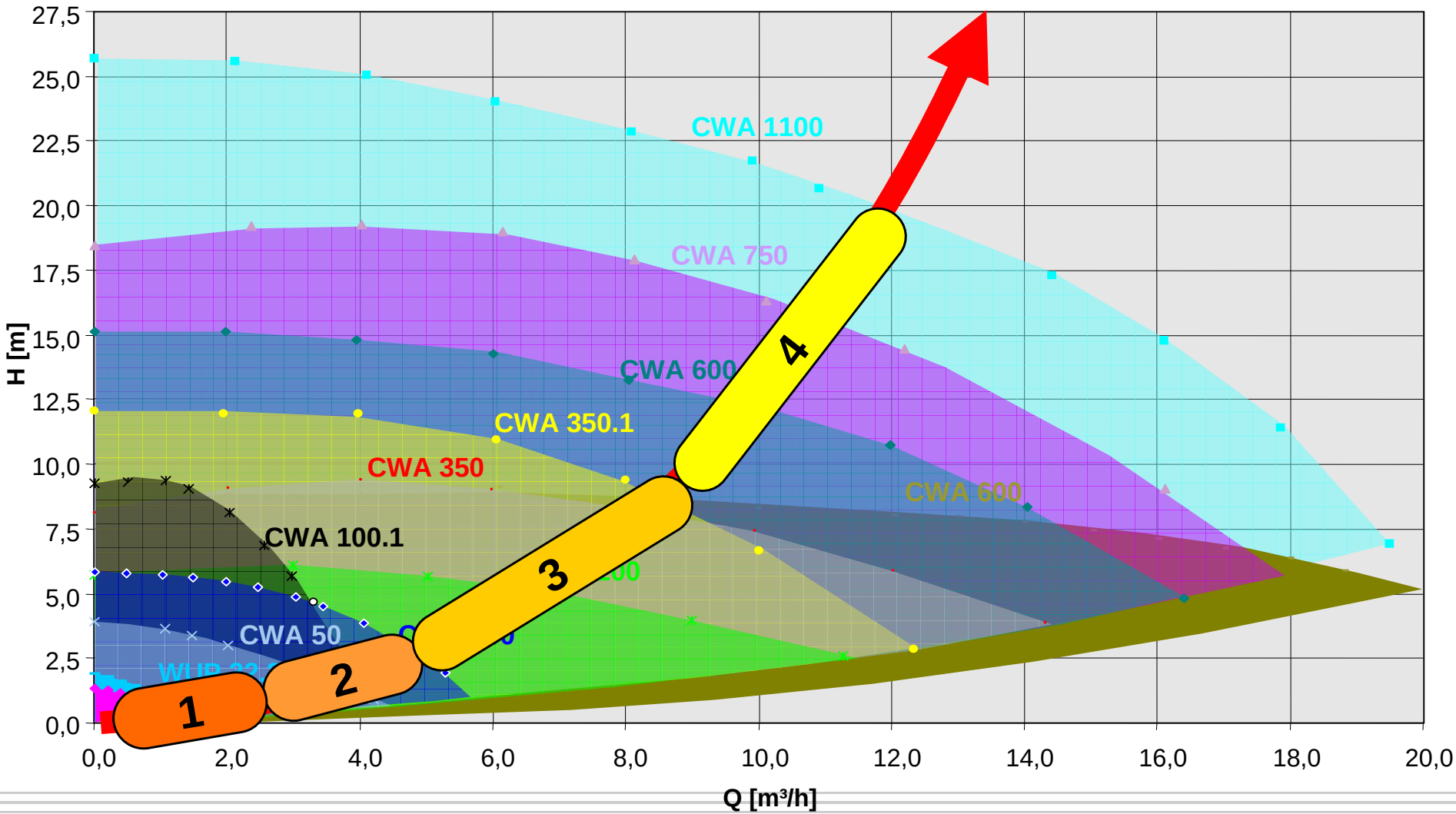
Field of application



Overview of the duty Graph of ECPs and application field

4

Hydrogen fuel cell cooling
Turbo charger cooling, ...



Introduction electrical main cooling pumps

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first vehicle with electrical coolant pump

serial production since 2004

Cabrio 630 i

Limousine 730 i

Coupe 630 i

Electrical coolant pump for the new BMW Inline Six-Cylinder and new 4-cylinder generation Otto Engine (front view)

Motorvarianten:

X30 i
Hubraum: 2996 ccm
Leistung: 190 kW

X25 i
Hubraum: 2497 ccm
Leistung: 160 kW

X23 i
Hubraum: 2497 ccm
Leistung: 130 kW

X20 i
Hubraum: 1995 ccm
Leistung: 125 kW

Advantages of the electrical coolant pump

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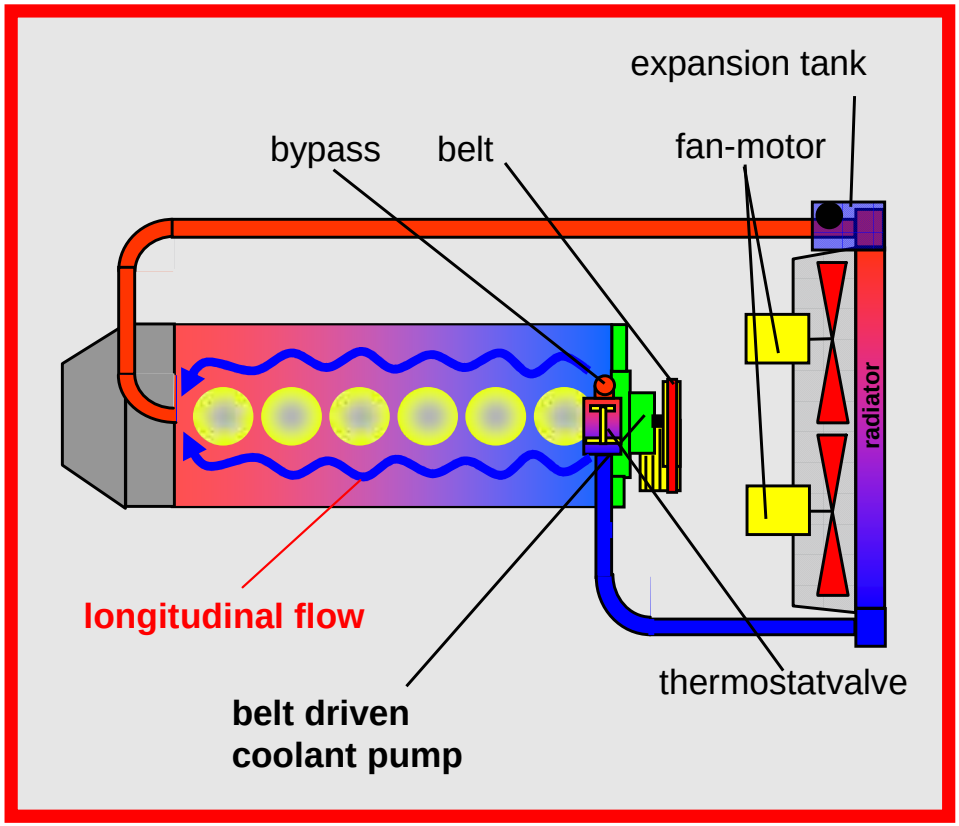
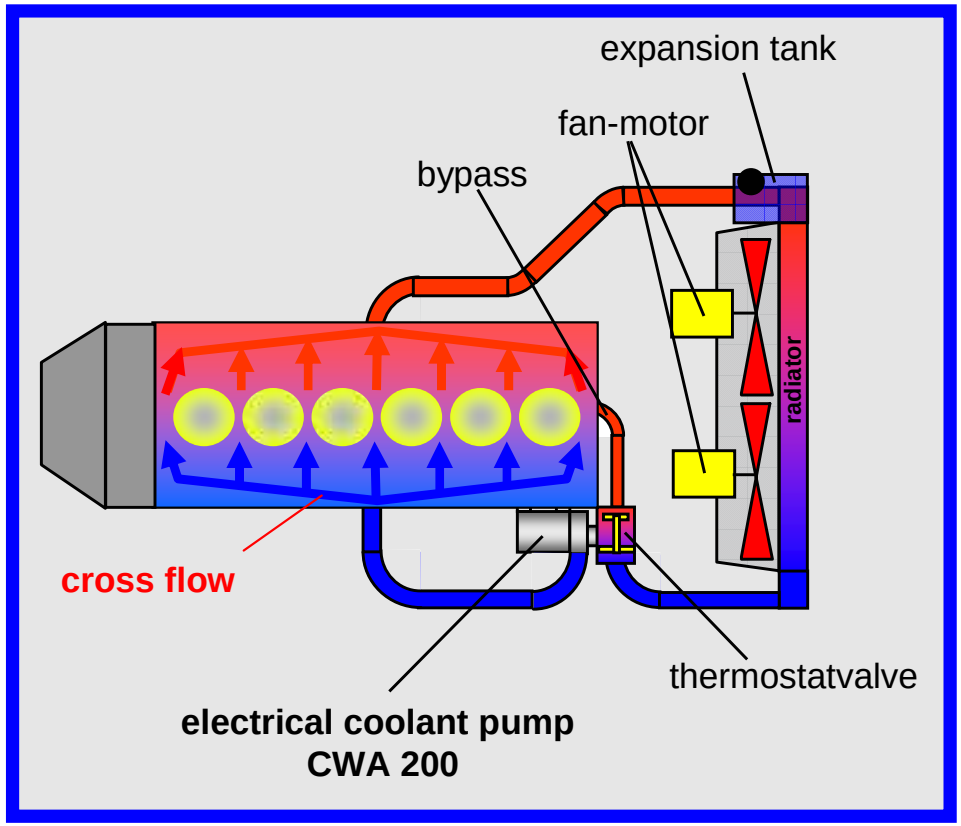
System comparison

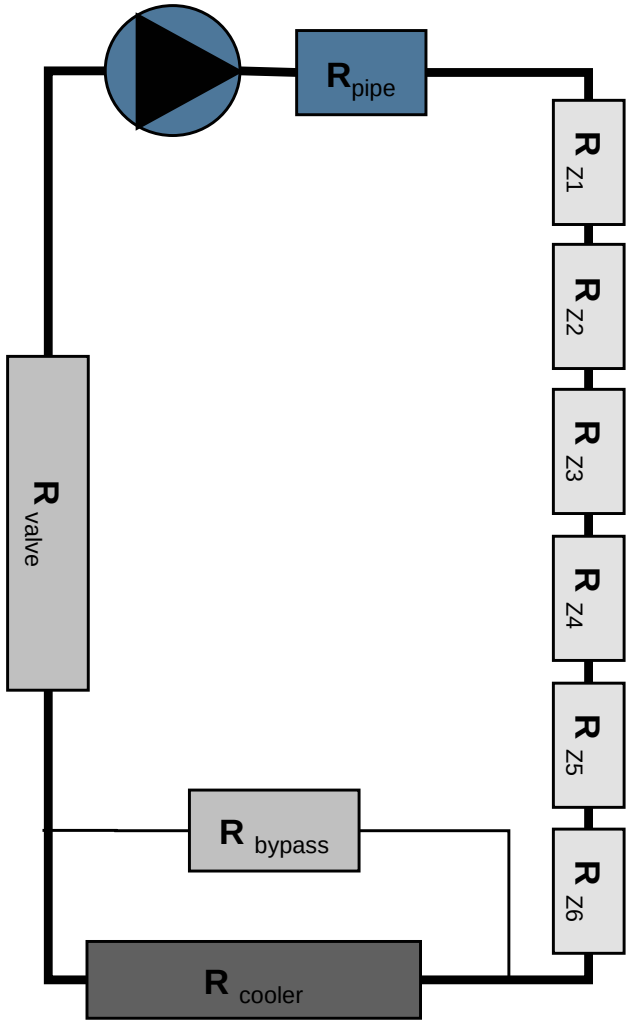
Combustion engine with belt driven coolant pump

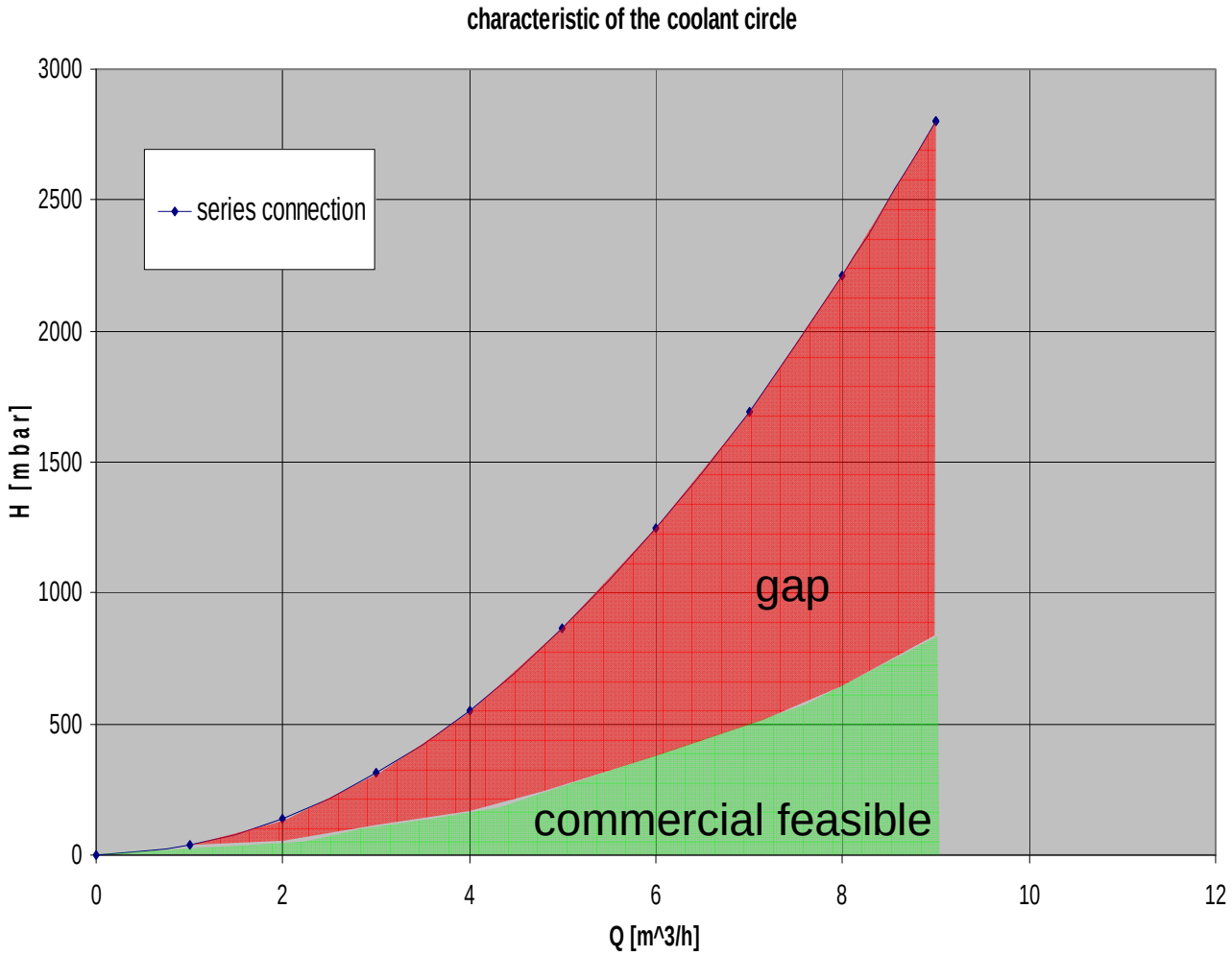


Combustion engine with electrical driven coolant pump

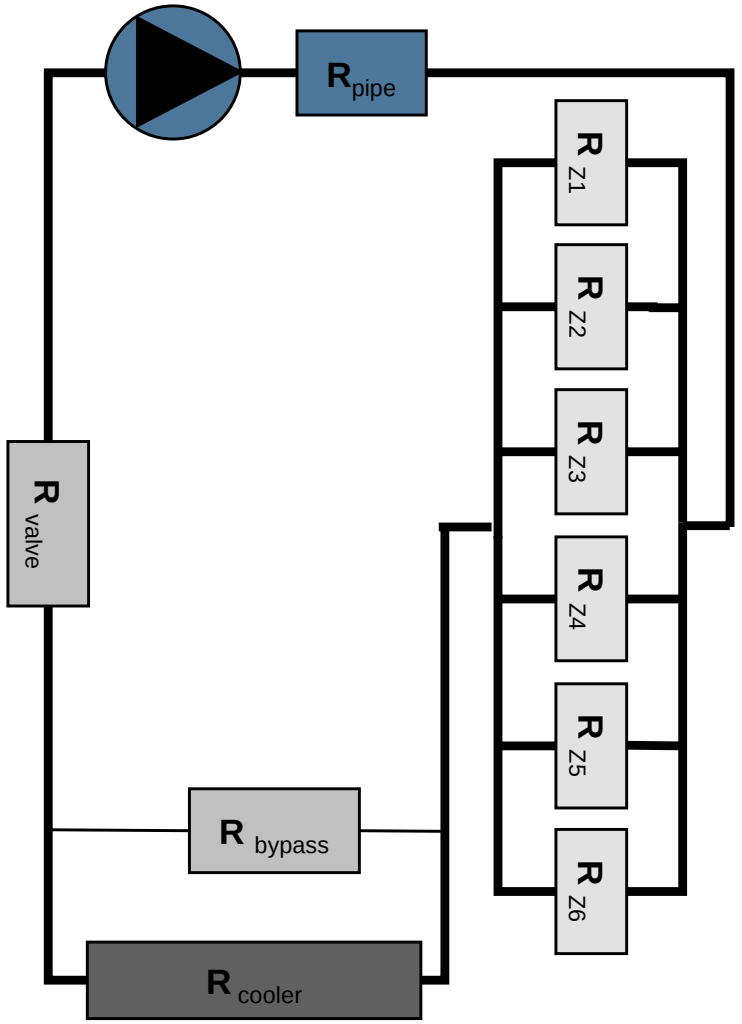


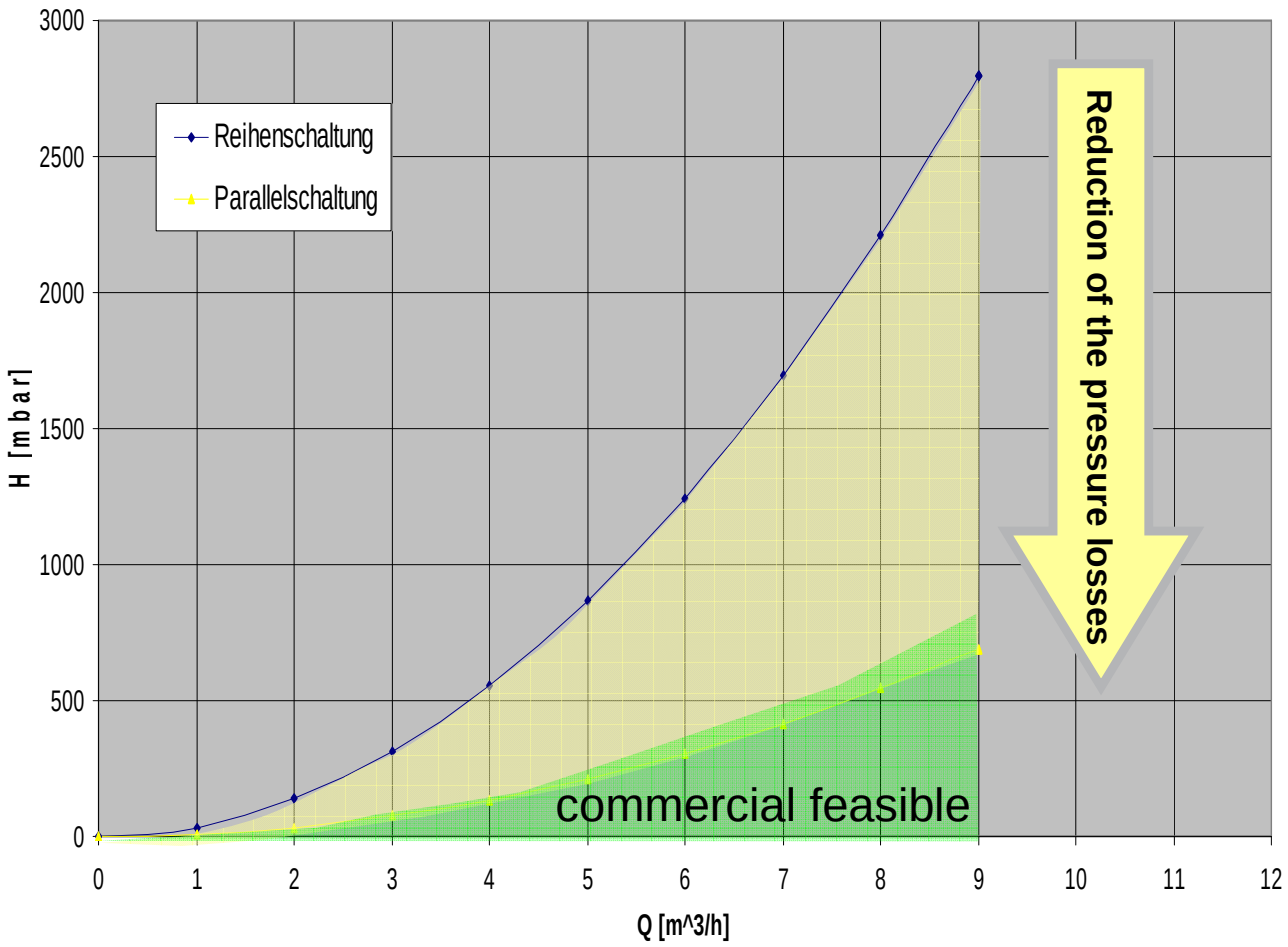
Resistances in the cooling system
Standard: cylinder into series connection





Resistances in the cooling system
Optimize: cylinder into parallel connection





Feature of the electrical driven coolant pump

- **variable speed of coolant pump, which is independent of combustion engine speed** ⇒ capacity adapted cooling enable**.**
- **control of coolant pump speed by several control variables possible (T_O , T_I, ΔT, v_{car}, Δp, $\Phi_{throttle\ valve}$, n_{CE}, T_{part}).**
- **after-running of coolant pump is possible** (with switched off combustion engine)**.**
  - ⇒ residual heat use for the raise the comfort
  - ⇒ prevention of „hot spots“ and “hot soaking”, relax requirements for cooling components → cost savings
  - ⇒ necessary for “start / stop” systems
- **flexible location of mounting**
  - ⇒ possible assembly with other components (radiator, fan, thermostat valve); simpler assembly.
  - ⇒ escape the second belt level more possible=>Improvement in the pedestrian protection
- **maintenance-free** (wet-runner motor ⇒ no rotating mechanical seal).
- **improved total efficiency ($\eta_{tot} > 50\% \Leftrightarrow \eta_{tot} = \eta_{motor} * \eta_{pump}$).**

Feature of the electrical driven coolant pump

- **Reduction of exhaust-emission**

⇒ shorter warm-up period

⇒ through **initial zero capacity** (pump revolutions per minute n = 0)

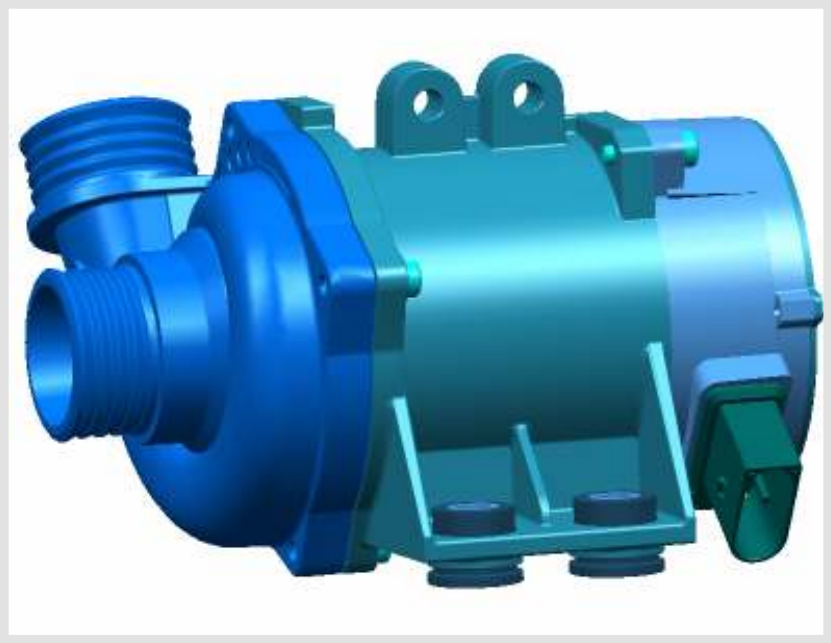
⇒ **faster warming of the oil**

⇒ **reduction** of friction losses
⇒ **improvement** of the internal combustion process
⇒ **reduction of the fuel consumption => aprox. 2%to 3%**
⇒ **reduction** of exhaust-gas emission

Comparison different types of waterpumps

Feature	mechanical waterpump	clutched mech. waterpump	variable mech waterpump	electrical waterpump
zero flow at cold start	no	yes	no	yes
variable speed of pump	no	no	limited	yes
after running function	no	no	no	yes
compatible for start / stop	no	no	no	yes
compatible for hybrid appl.	no	no	no	yes
maintenance free	no	no	no	yes
improoved efficiency	possible	possible	possible	yes
high coolant flow at low engine speed	no	no	no	yes

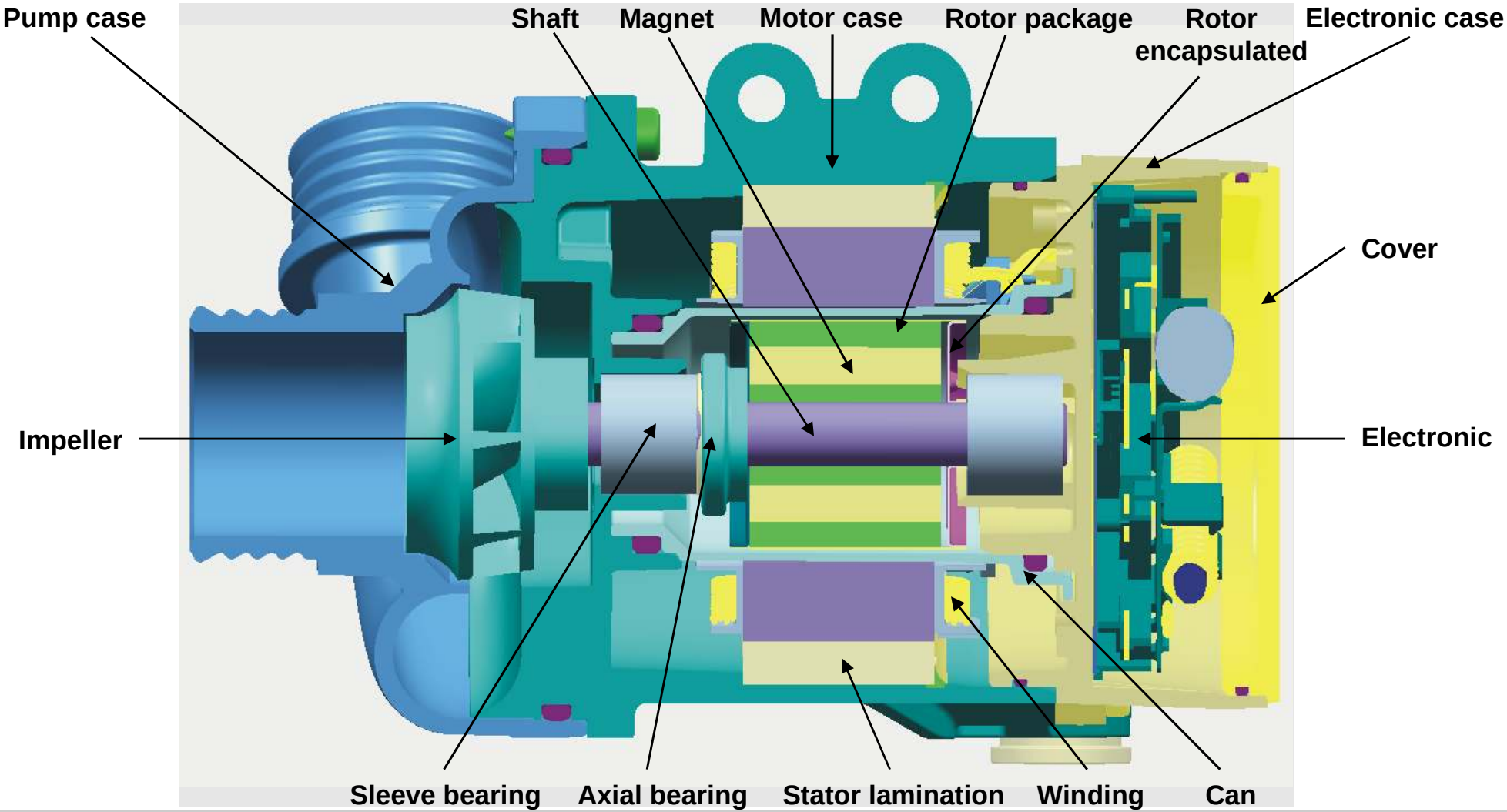
Series type CWA 200



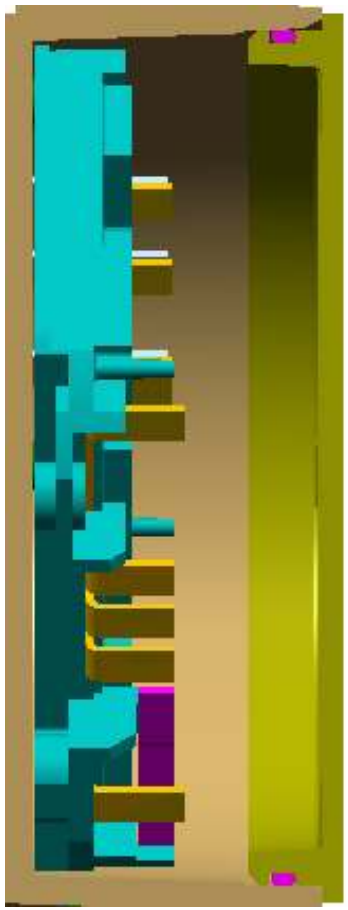
Features

Pump duty point	Q=7000 l/h / H=0,45 bar
Ambient temperature	-40℃ ... +140℃
Coolant temperature	-40℃ ... +128℃
Voltage supply	min. 10 V max. 18 V
Power consumption P_1	200 W
nominal Current	16 A
Quiescent current	<100 µA
Min. lifetime	l_h = > 6000 h
Interface	PWM, LIN, ...
Enclosure	IP 67

Series design of CWA 200



Electronic



Functions

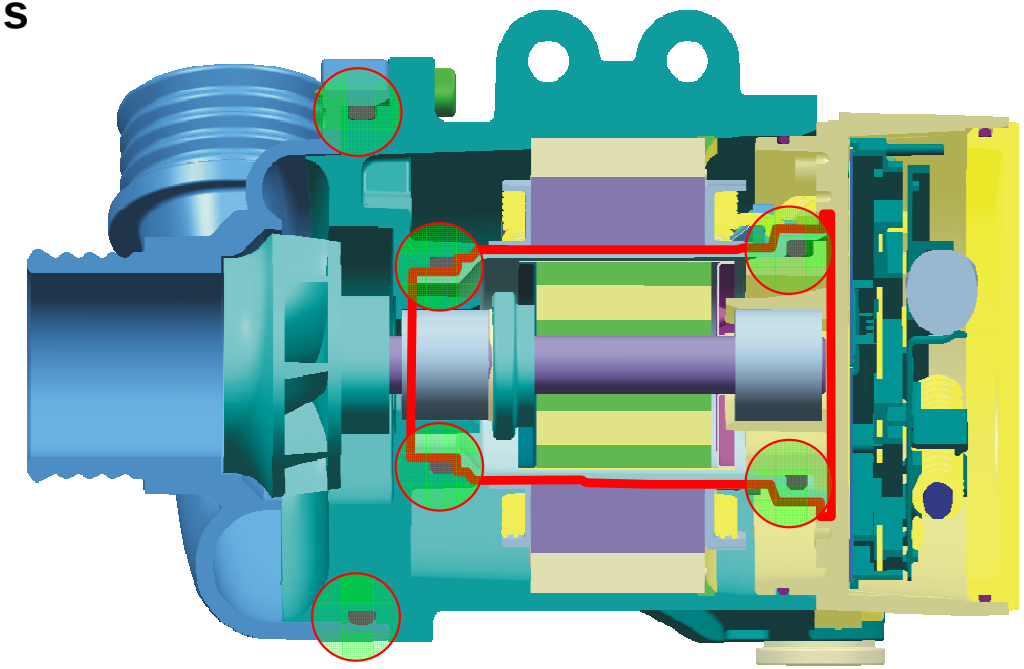
- **speed control via an external BUS - signal**
- **system diagnostics (actual speed, temperature, current, blocking)**
- **overload protection**
- **overvoltage protection**
- **overtemperature protection**
- **dry running protection**
- **deblocking function**

Failure Protection

Mechanical Parts (except bearings)

the choosen design of the pump guaranty‘s

- **a maintanance free pump**



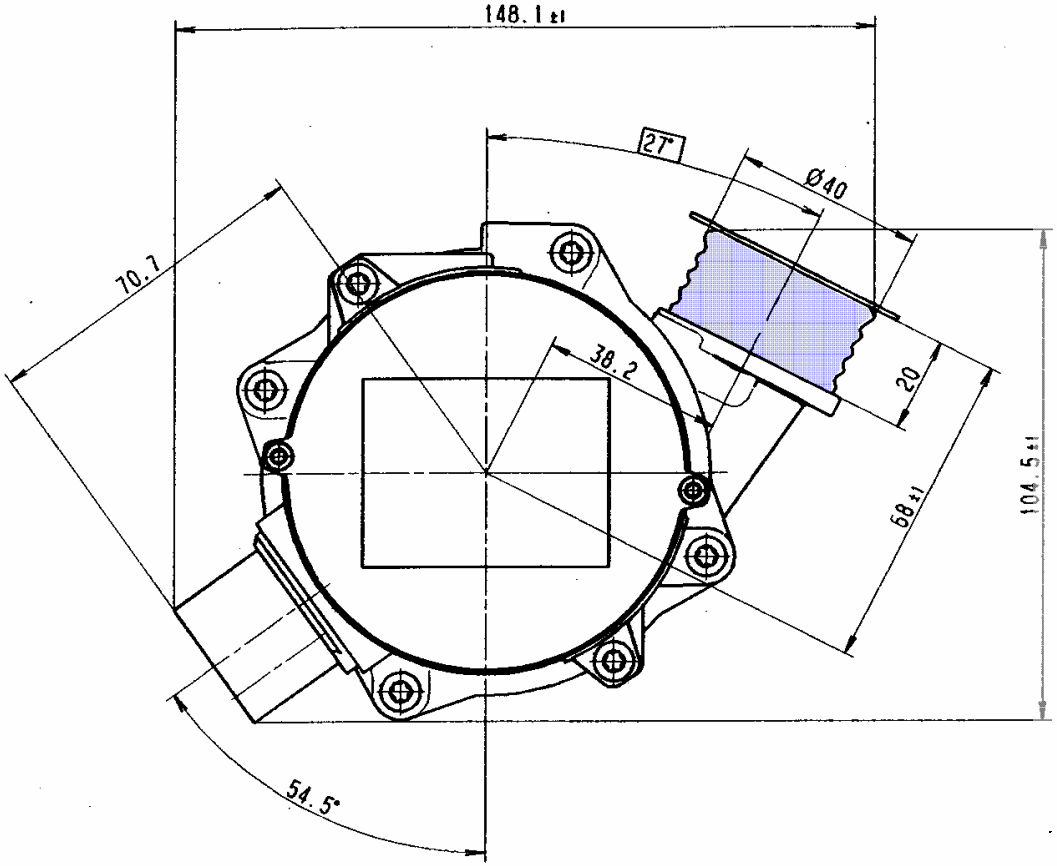
Wet-Runner-motor

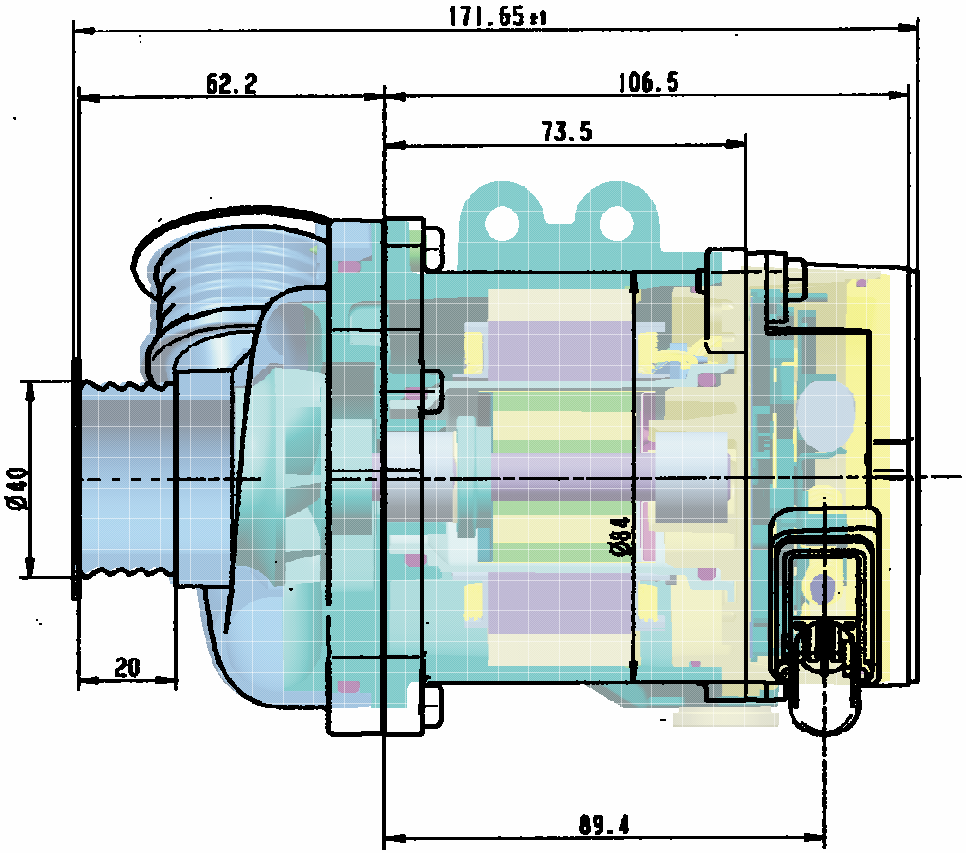
- **no dynamic sealings**
- **no wear of the sealings**
- **no limiting in lifetime**

BLDC-Motor

- **eliminating the mechanical commutation**
- **fully encapsulated rotor protect rotor from corrosion**
- **stator coil without centrifugal force (no rotation)**
- **no limiting in lifetime**

Dimension CWA 200





weight: ~2250g

Indirect charge air and EGR-cooling and hybrid application with CWA 50

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CWA 50 / 100

Applications

- **charge air cooling**
  - improved package
  - increasing engine power
  - reducing emmision (NOx)
  - reducing fuel consumption
- **hybrid applications**
  - battery cooling
  - electronic cooling
  - heater booster cabin
- **electric vehicle**
  - cooling battery charging electronic
  - power electronic cooling
- **miscellaneous**
  - transaxle cooling

CWA 50 / 100

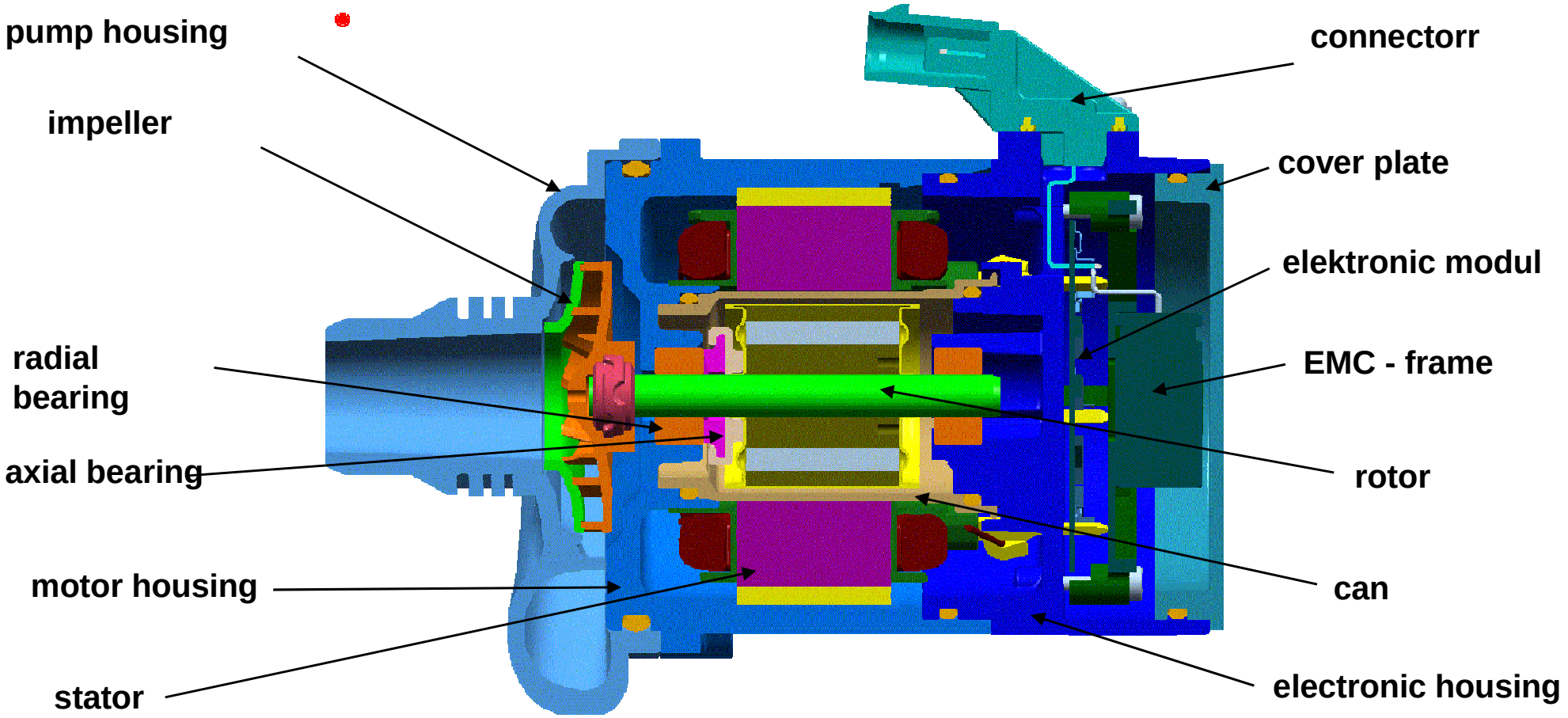
Features

Pump duty point CWA50	Q=1.500 l/h / H=0,55 bar
CWA100	Q=1.800l/h / H=0,85 bar
Ambient temperature	-40℃ ... +140℃
Coolant temperature	-40℃ ... +128℃
Voltage supply	min. 10 V max. 18 V
Power consumption P_1	65 / 130 W
Min. lifetime	l_h = > 6000 h l_h = 20.000 h ?
Interface	PWM, LIN, ….

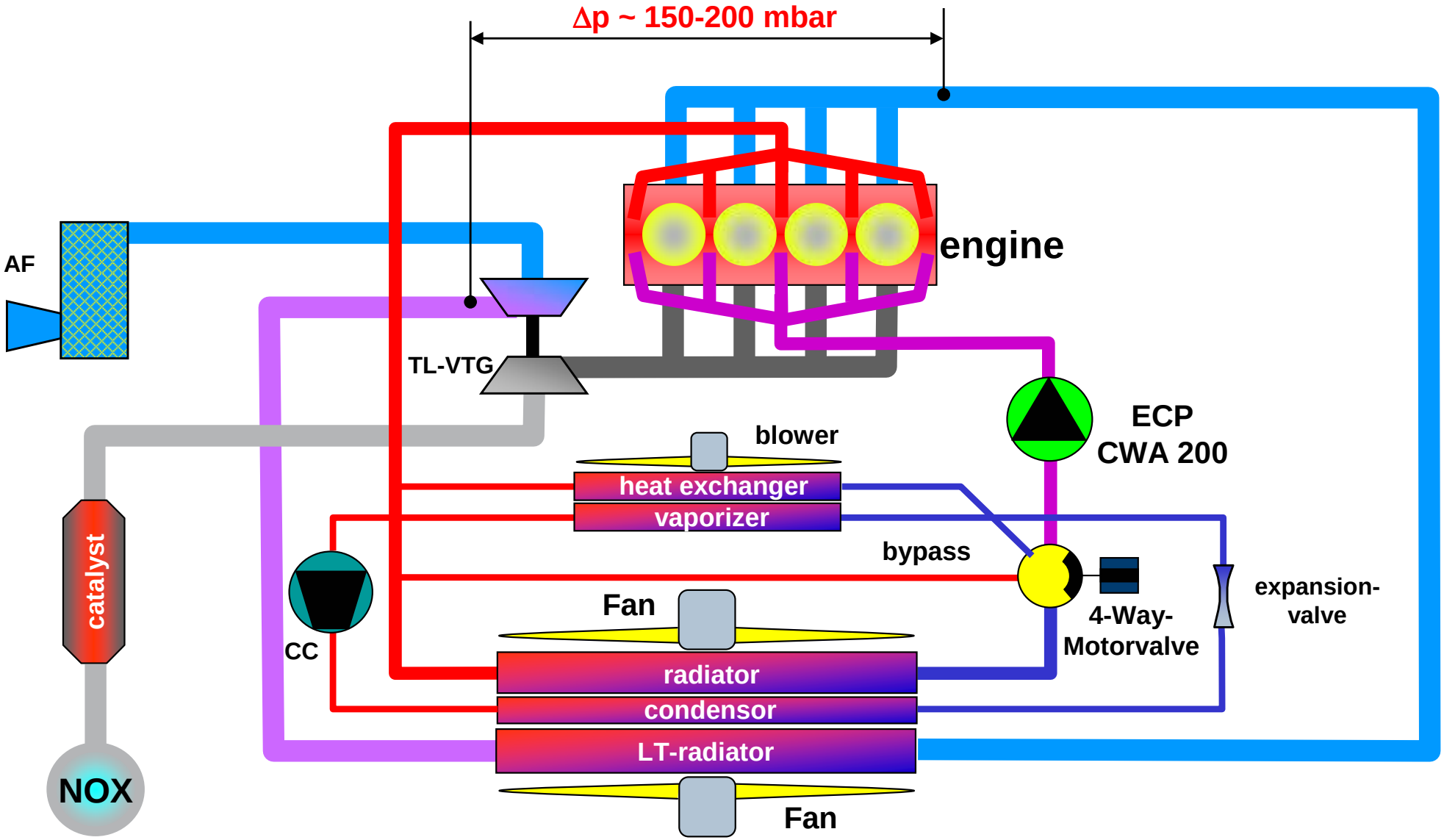
Status

- serial production since 2008 for CWA50
- start serial production with CWA100 in 2010
- several variants in production

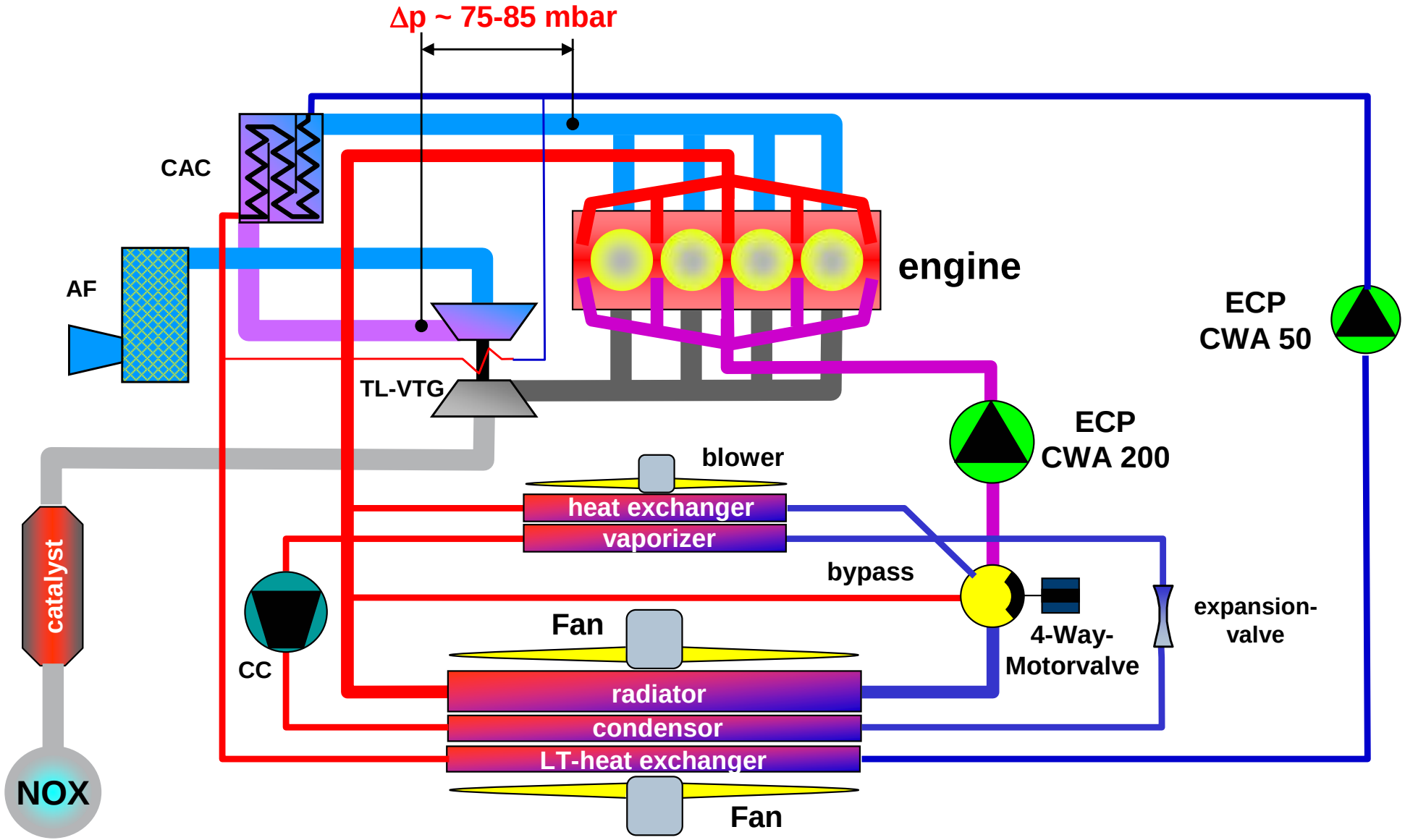
Construction CWA 50



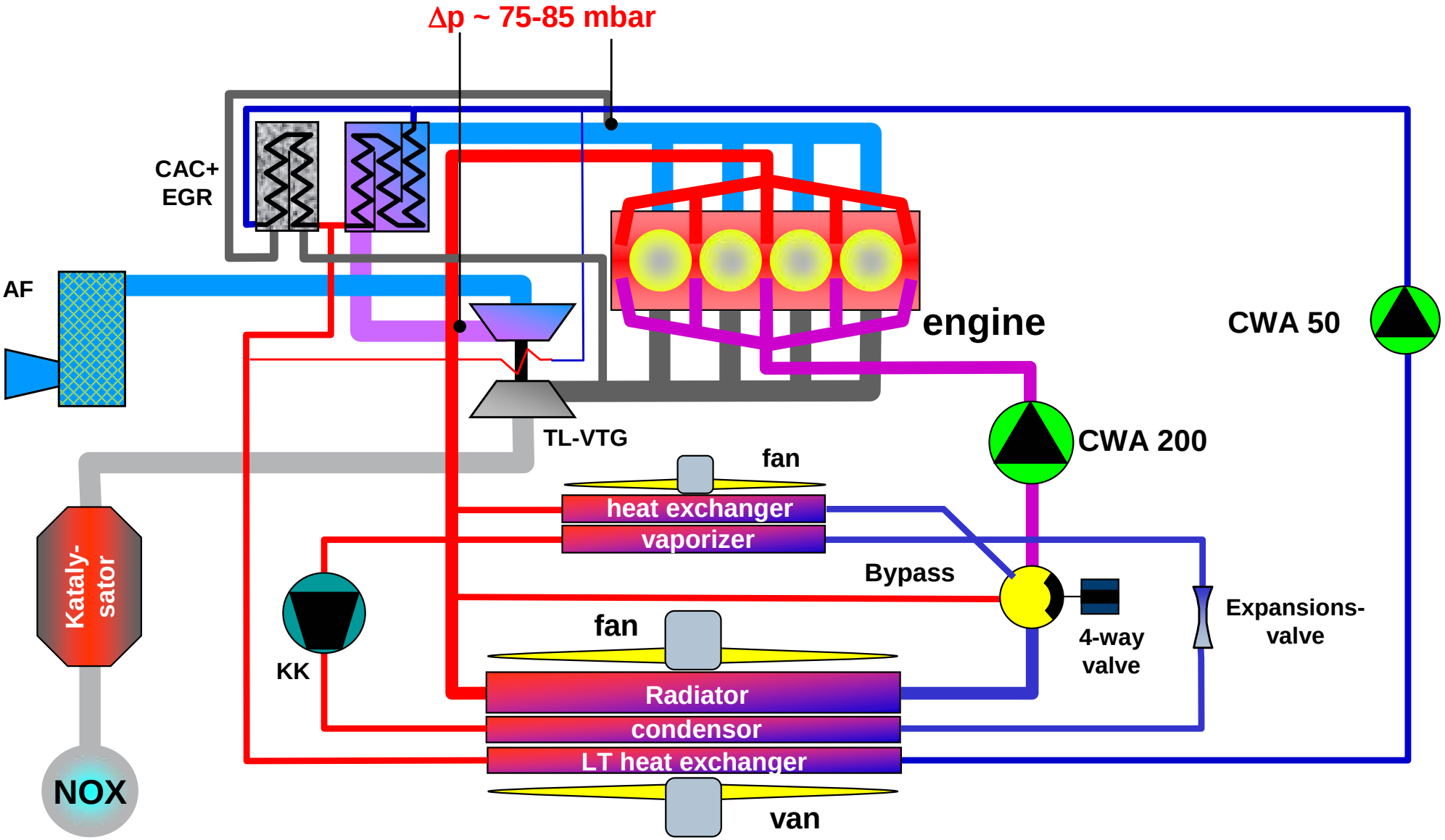
direct charge air cooling



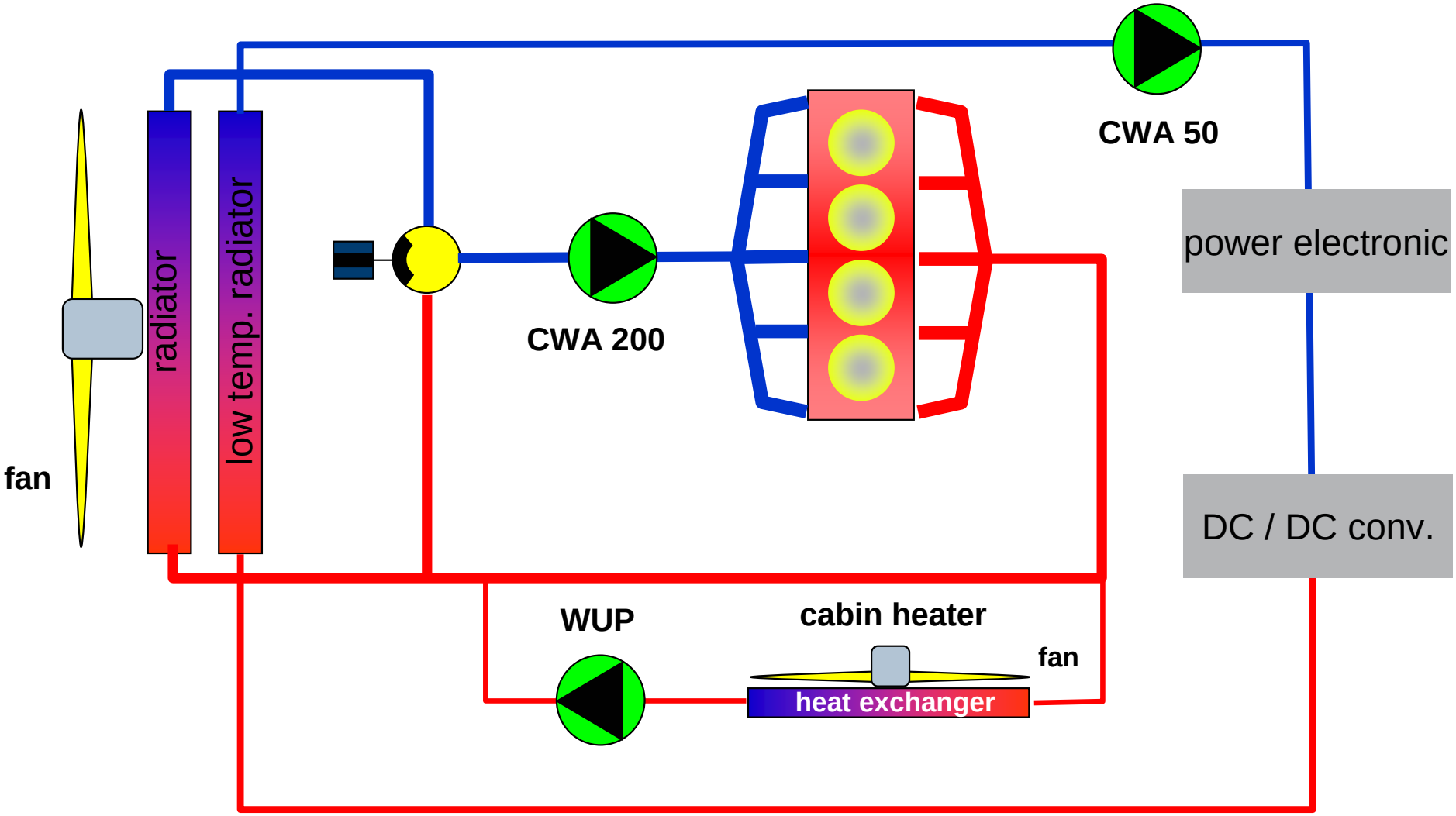
indirect charge air cooling



indirect charge air cooling and EGR-cooling



Hybrid application



Feature of indirect charge-air cooling with the electrical coolant pump

- **improved Package situation**
  ⇒ Air-sided pipework is fundamentally simpler

- **reduction of the air-sided losses of pressure around approx. 50%**
  ⇒ A better cylinder fill factor results from this with same turbocharger

- **reduce the thermal stress of the engine**
  ⇒ Raise of the knock resistance (Otto engine).

- **reduce the exhaust gas temperature**
  ⇒ Reduction of the NOx emission (diesel engine).

- **reduce the fuel consumption**
  ⇒ Reduction of the exhaust emission.

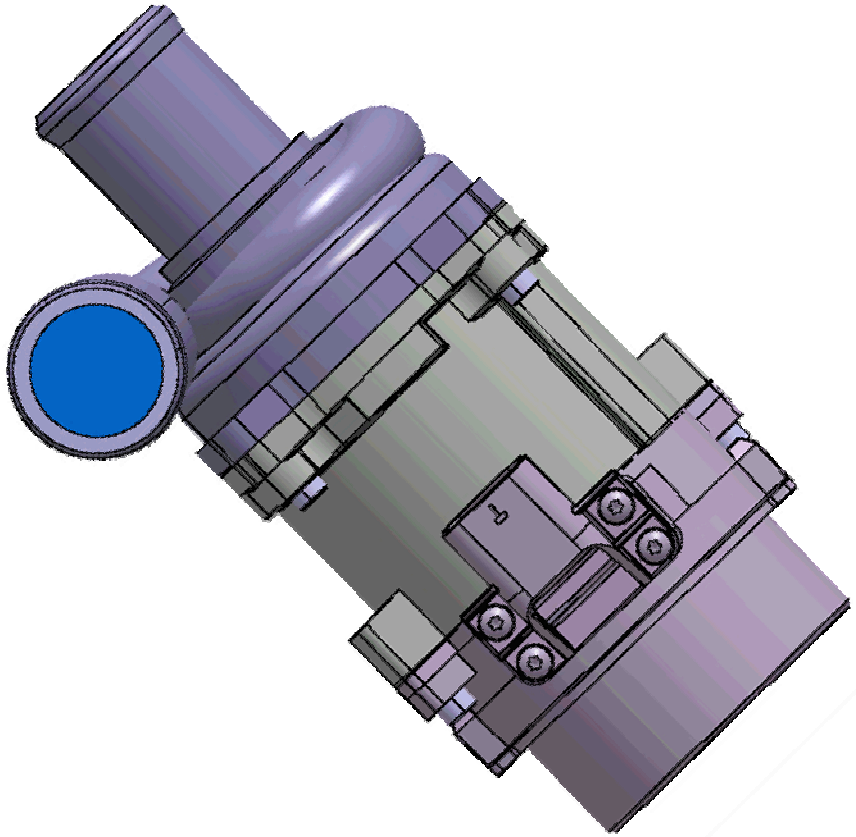
- **flexible location of mounting (air-water heat exchanger and pump)**
  ⇒ Possible assembly with other components.

Technical datas CWA 50

Features

Pump duty point	Q=1.500 l/h / H=0,55 bar
Ambient temperature	-40℃ ... +140℃
Coolant temperature	-40℃ ... +128℃
Voltage supply	min. 10 V max. 18 V
Power consumption P_1	65 W
Max. current	6 A
Quiescent current	<100 µA
Min. lifetime	l_h = > 6000 h
Interface	PWM, LIN, ….
Enclosure	IP 67

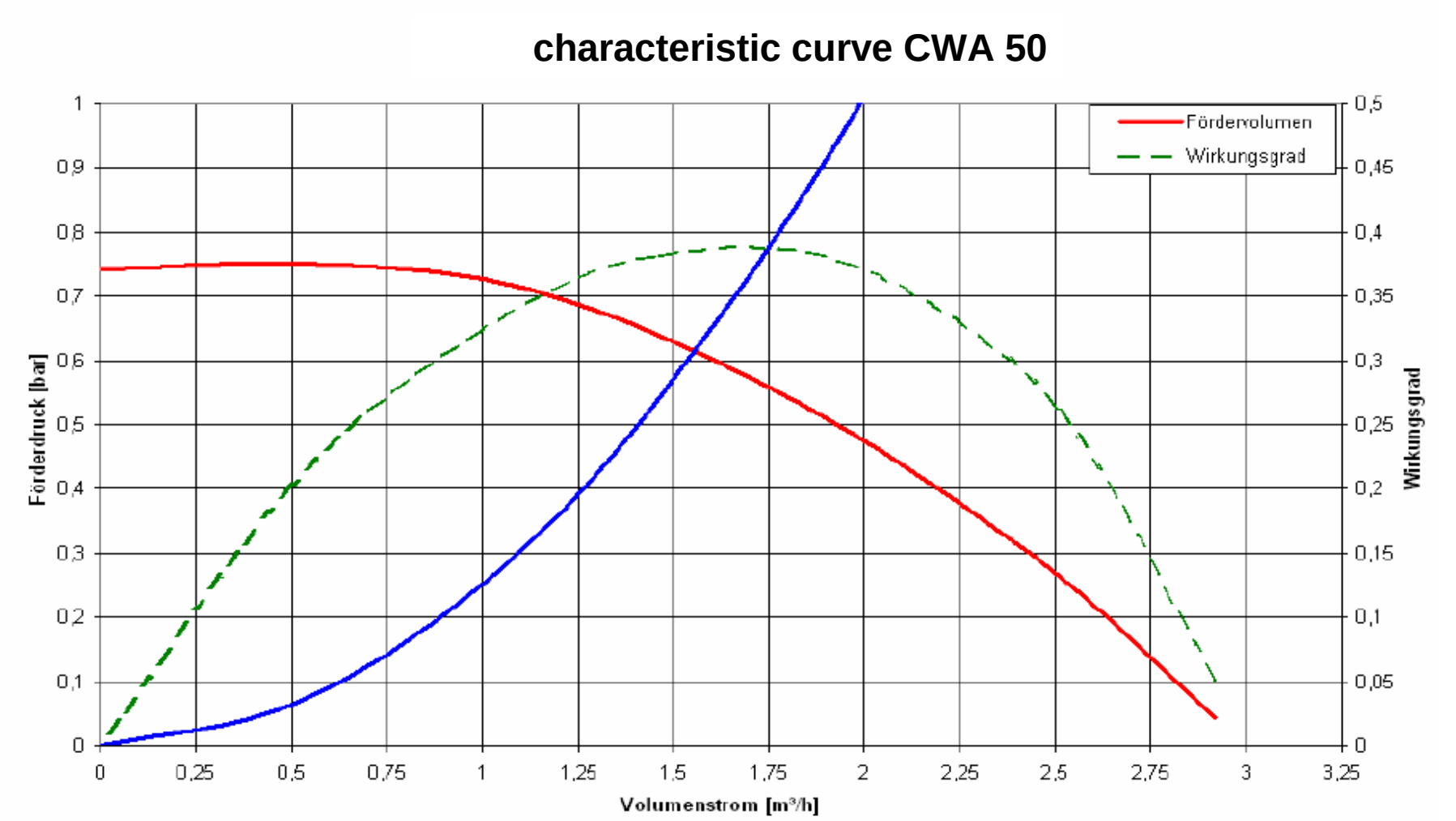
Technical datas CWA 100



Features

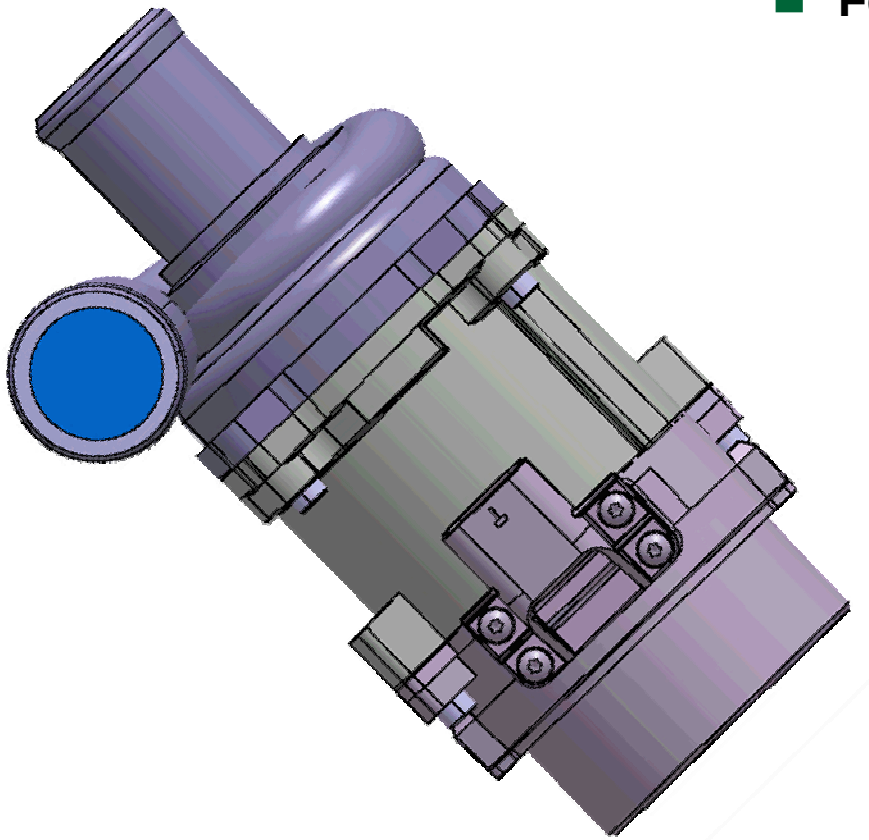
Pump duty point	Q=1.800 l/h / H=0,9 bar
Ambient temperature	-40℃ ... +140℃
Coolant temperature	-40℃ ... +128℃
Voltage supply	min. 10 V max. 18 V
Power consumption P_1	125 W
Max. current	10 A
EMC	stand.spec.
Quiescent current	<100 µA
Min. lifetime	l_h = > 6000 h
Interface	PWM, LIN, ….
Enclosure	IP 67

Hydraulic characteristic data CWA50



Technische Daten CWA 100.2

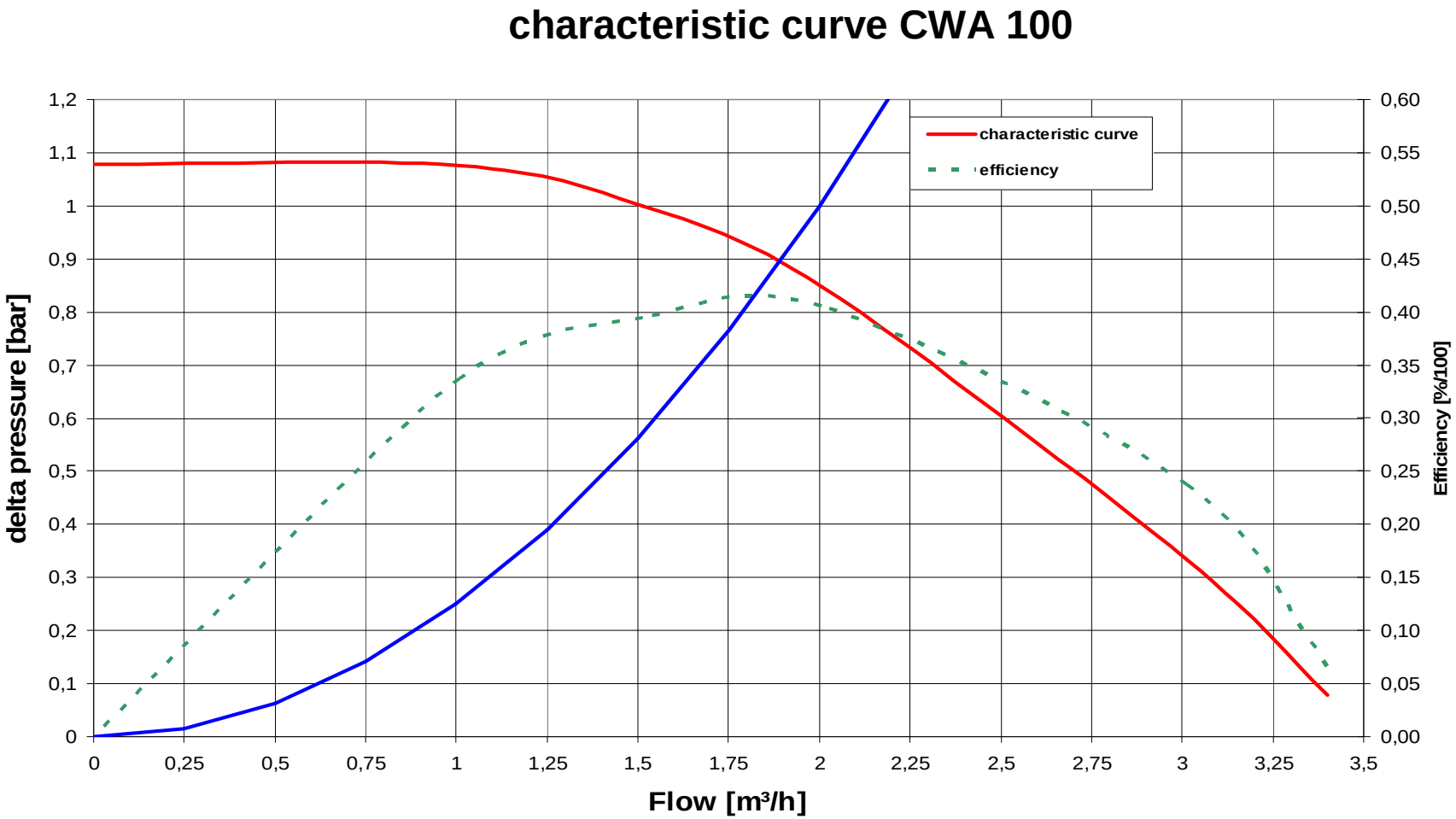
Overview



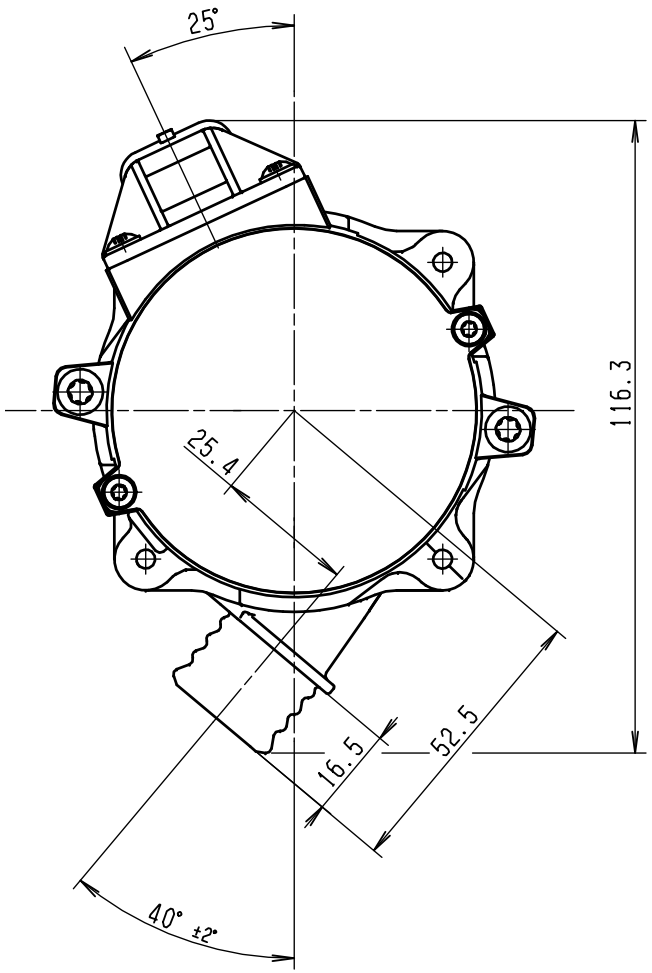
Features (nominal)

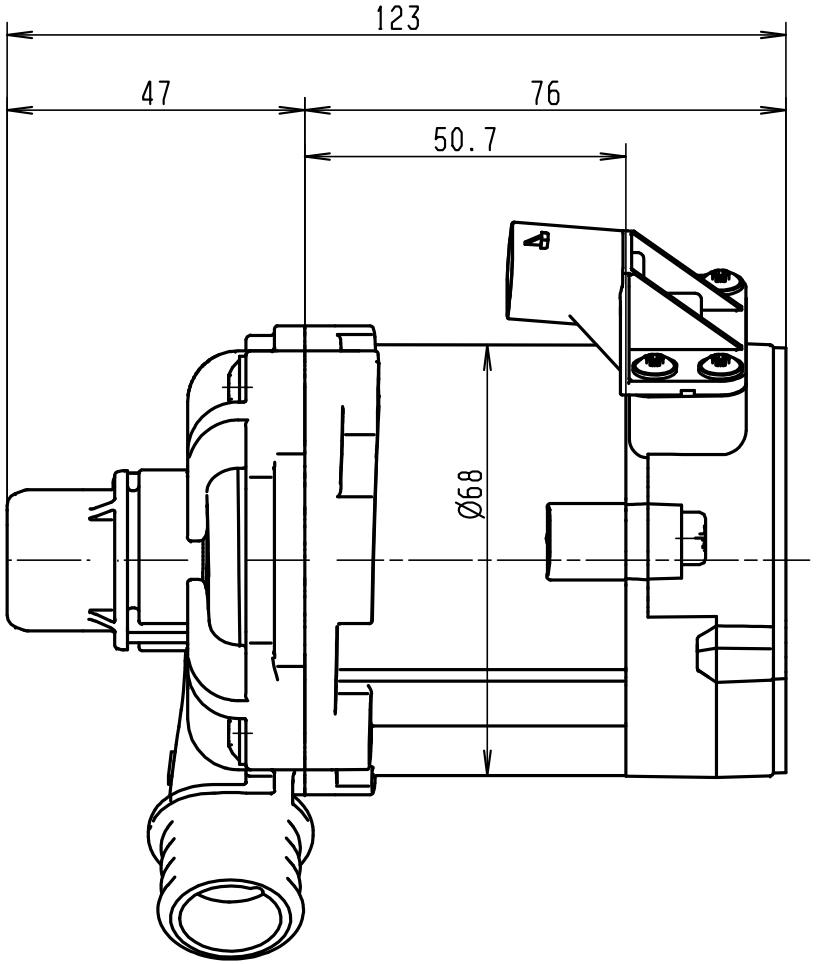
Nennpunkt	Q=1800 l/h / Δp=0,9 bar
Umgebungstemperatur	-40℃ to 140℃
Mediumtemperatur	-40℃ to 128℃
Spannungsbereich	min. 8 V, max. 16 V
Leistungsaufnahme P_1	130 W
Stromaufnahme	< 10 A
Ruhestrom	< 100 µA
Lebensdauer	6000h
Schnittstelle	PWM, LIN
Schutzart	IP 67

Hydraulic characteristic data CWA100



Dimension CWA 50





Water Circulation Pump

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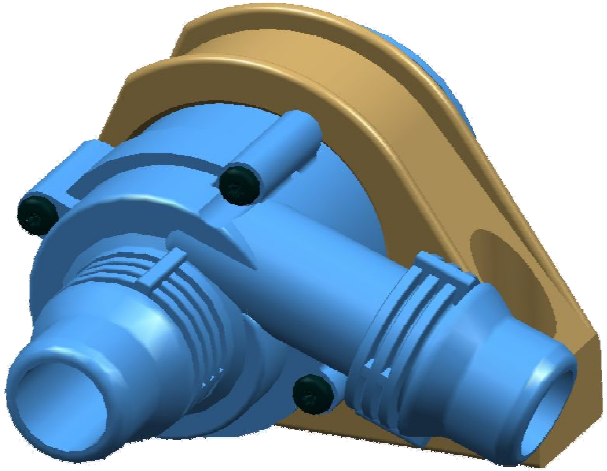
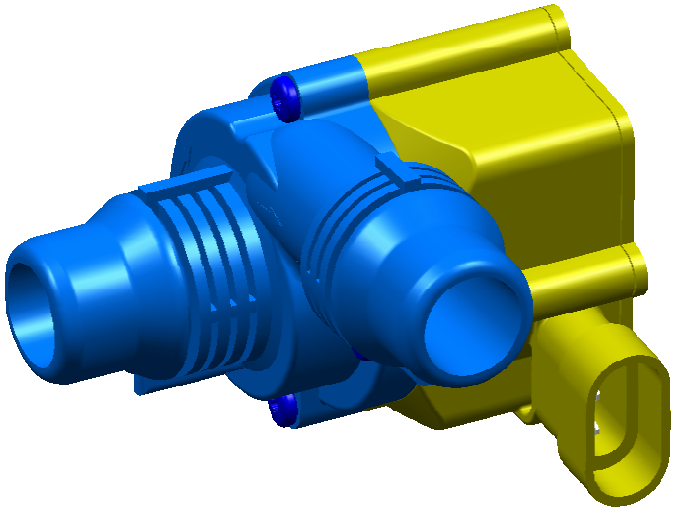
Water Circulation Pump

two generations of water circulating pumps



WUP1

- series production since 1996
- approved
- compact
- available in 12V and 24V
- immediately available



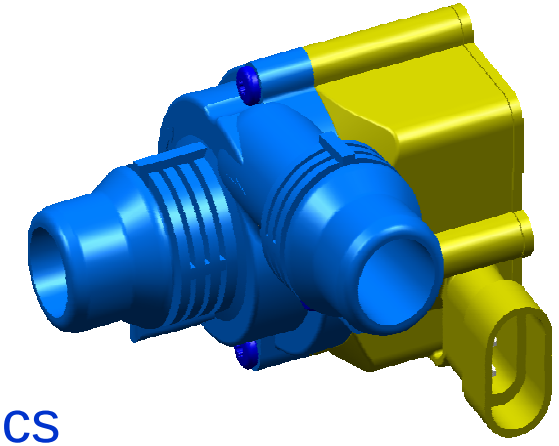
WUP2

- reduced length (-22mm)
- reduced weight (-70g)
- higher temperature durability
- adjustable pump speed (PWM)
- diagnostic signal

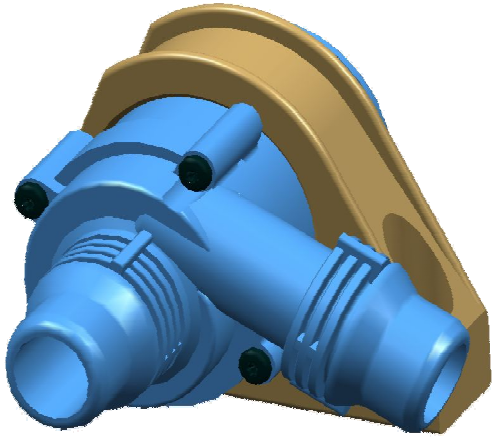
Applications

- car heating
- after boil pumps
- cooling for fuel systems
- cooling for power electronics
- parking heater systems
- air condition systems
- cooling for turbo systems

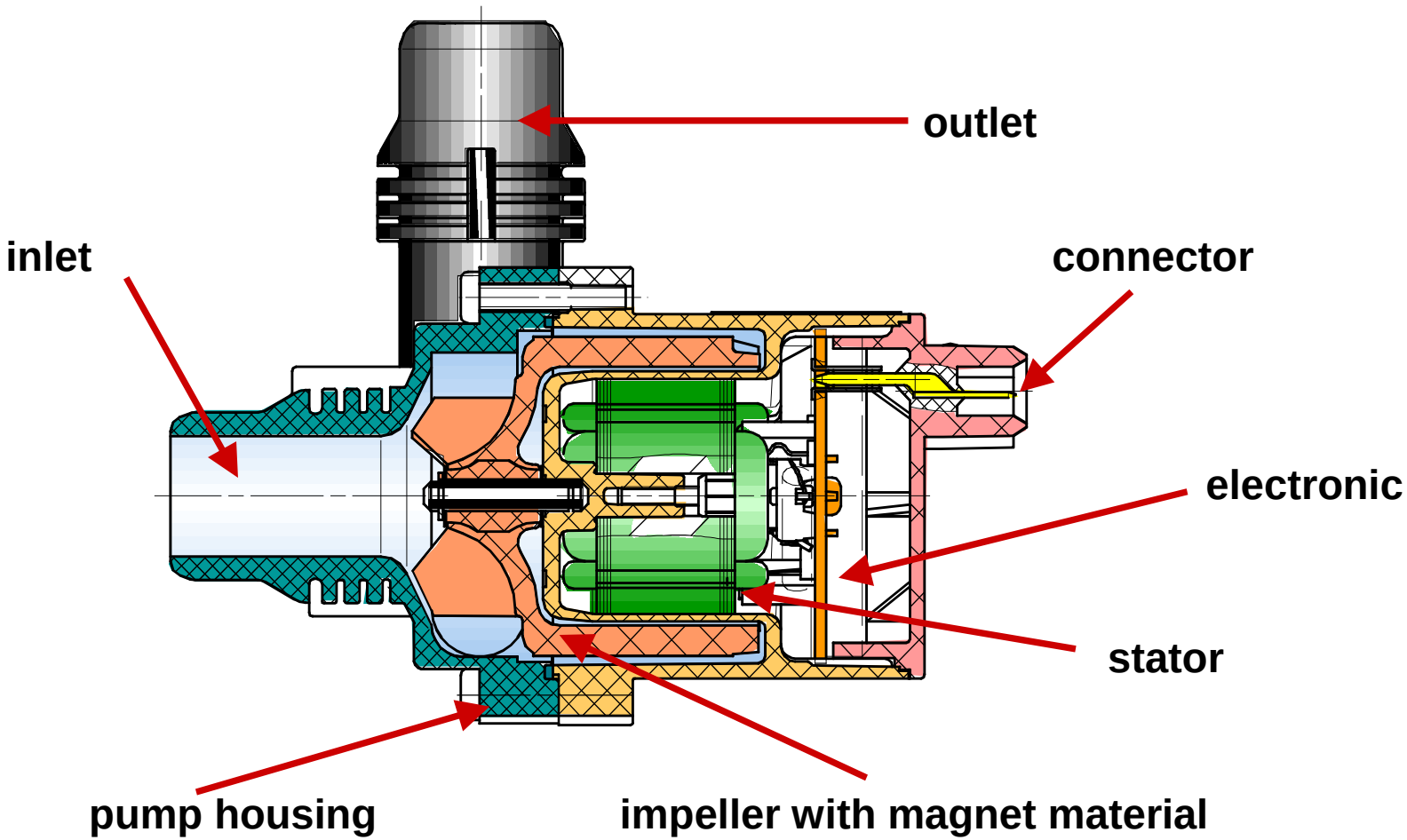
WUP2



WUP1



Water circulation pump

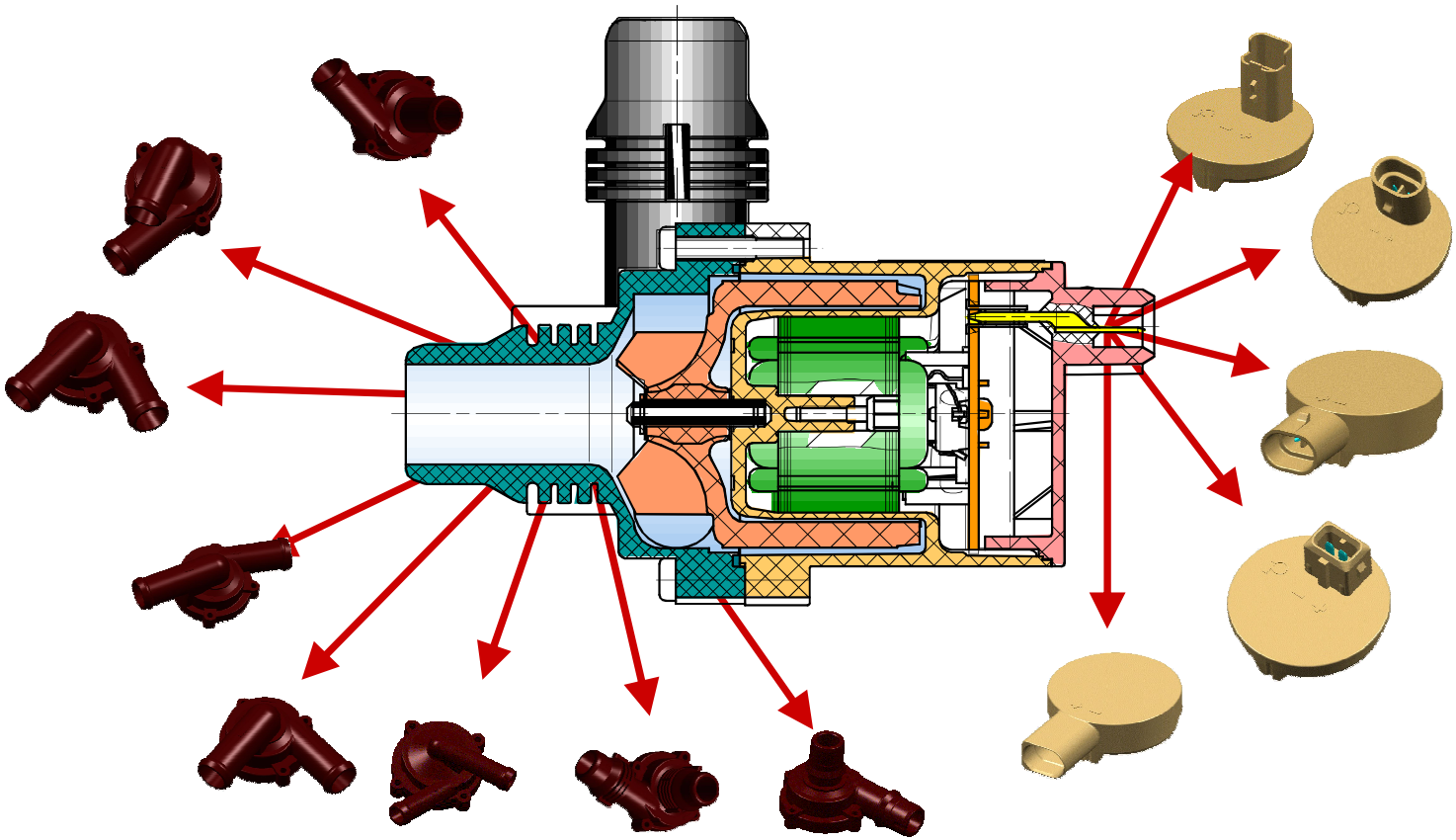


Water Circulation Pump

pumphousing / electrical connector

quantity of produced WUP

~ several million



Delphi axial

Delphi radial

Mini Timer axial

RD radial

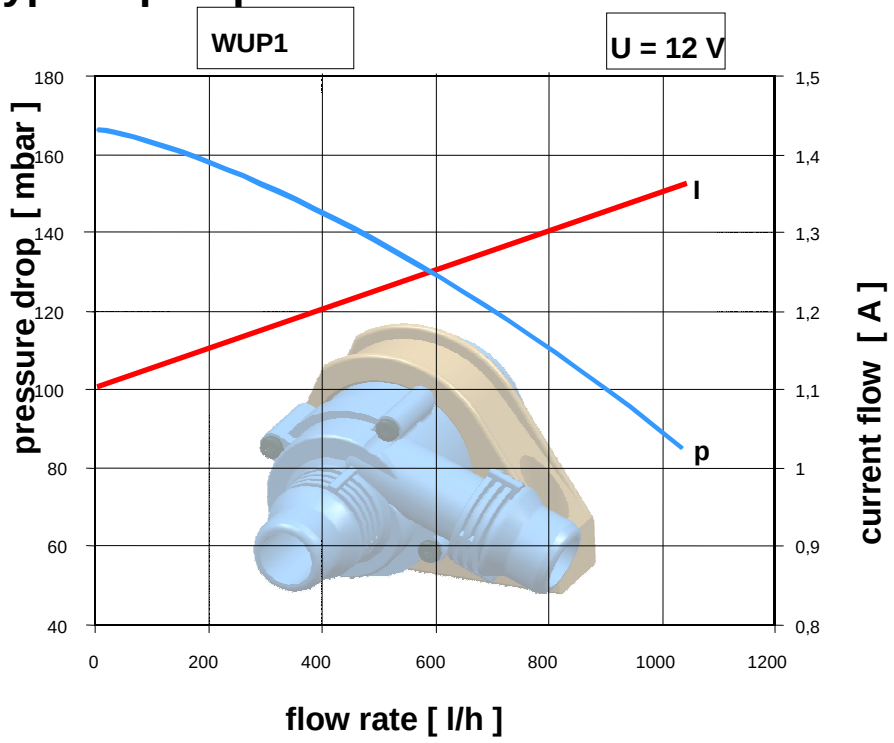
Sicma 2

Water circulation pump

technical data WUP 1

nominal voltage:	**12V**
voltage range:	**9…16V**
nominal point:	**>820 l/h@100mbar (12V, 23℃, coolant: 50/50%)**
current consumption:	**<1,5A (12V, 23℃, working point)**
temperature range:	**-40…135℃**
mass:	**280g (without bracket)**
protection level:	**IP 54K**

typical pump characteristic



Vielen Dank für
Ihre Aufmerksamkeit !

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Failure Protection CWA50 – CWA400

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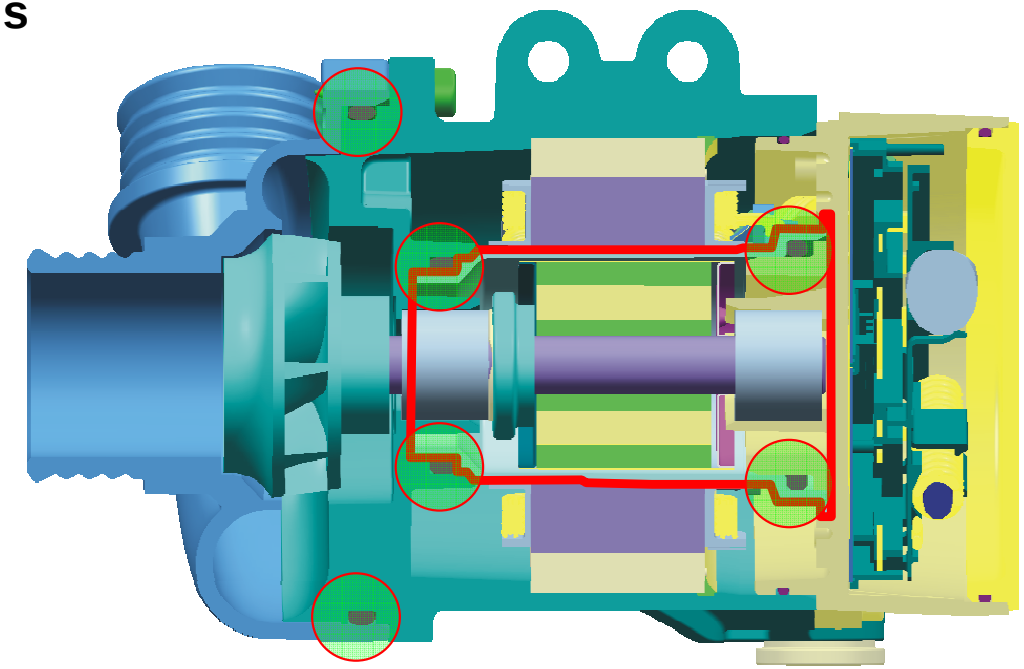
Failure Protection

Mechanical Parts (except bearings)

the choosen design of the pump guaranty‘s

- **a maintanance free pump**



Wet-Runner-motor

- **no dynamic sealings**
- **no wear of the sealings**
- **no limiting in lifetime**

BLDC-Motor

- **eliminating the mechanical commutation**
- **fully encapsulated rotor protect rotor from corrosion**
- **stator coil without centrifugal force (no rotation)**
- **no limiting in lifetime**

Failure Protection

Bearings

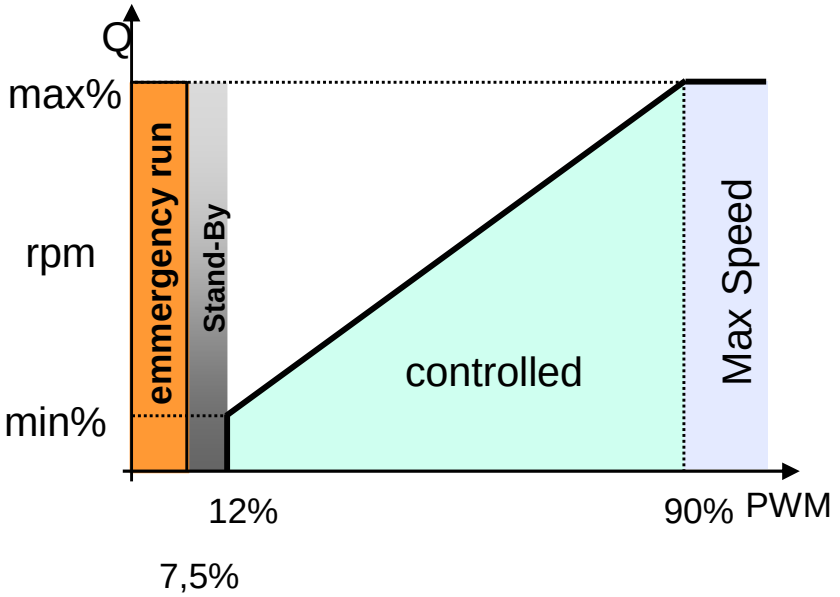
- know how transfer from pumps for heating systems in buildings transfered to the automotive pump.
- normal operation hours for heating system pumps are ~ 100.000h (>10y). Requirements for automotive is only ~6.000h
- forced ventilation of rotor room ensures lubrication for the bearings
- dry-run protection included in electronic module protect the bearings, if neccesary
- deblocking function included in electronic module to enable start of the pump in case of contaminated bearings

Failure Protection

Electronic Interface

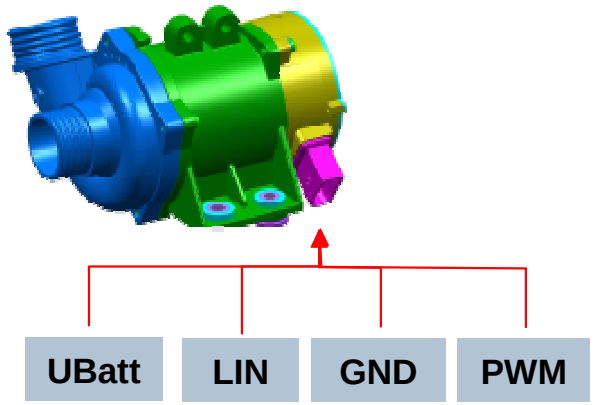
For operation with PWM interface

- **if signal is out of range (shortcut to GND or UBatt)**
  - **pump go to emmergency mode**



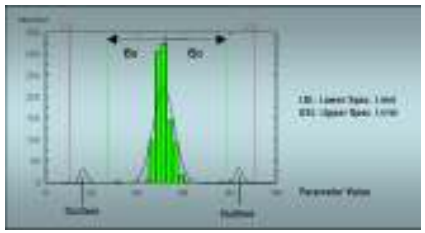
For operation with LIN / BSD interface

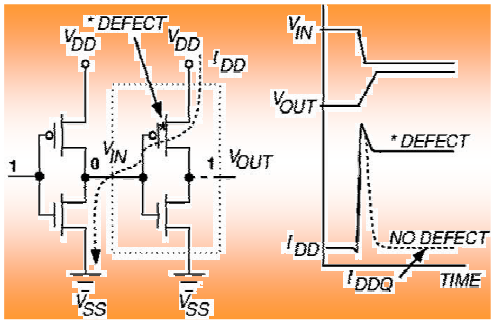
- **PWM input enables emmergency run**
  - **PWM input is connected to battery power (ignition on)**
  - **if timeout is reached on BSD / LIN interface, or message on the bus is not valid pump start automatically emmergency mode**



Failure Protection

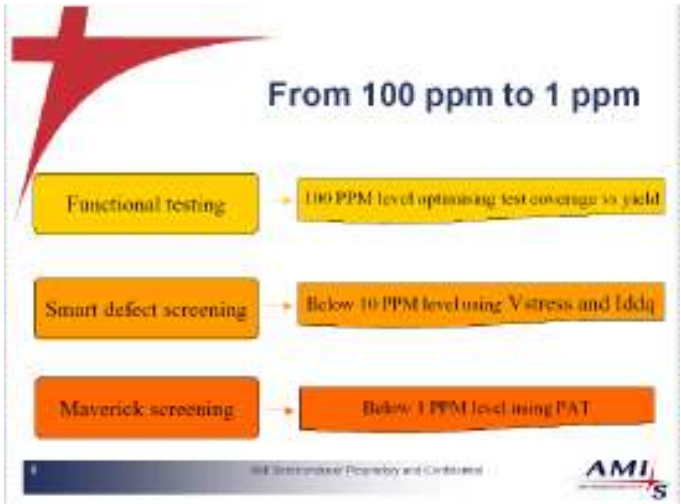
Electronic Module





Ensure Highest Quality Level

- Part Average Test
  - early detection of failures with statistical methods
- VStress Test
  - short time operation with high voltage and measurement of leak current before % after test
- IDDQ Test (quiscent current)
  - method to find defects on ASIC and electronic modul



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thanks for your attention

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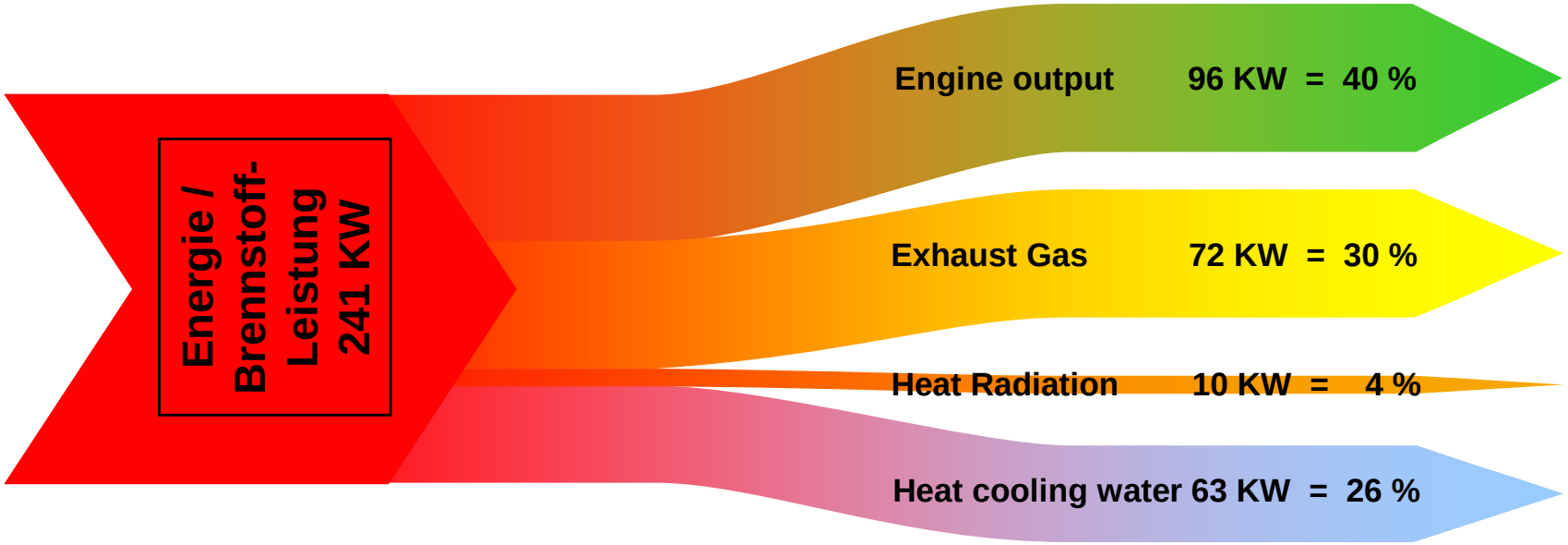
Sankey Diagramm

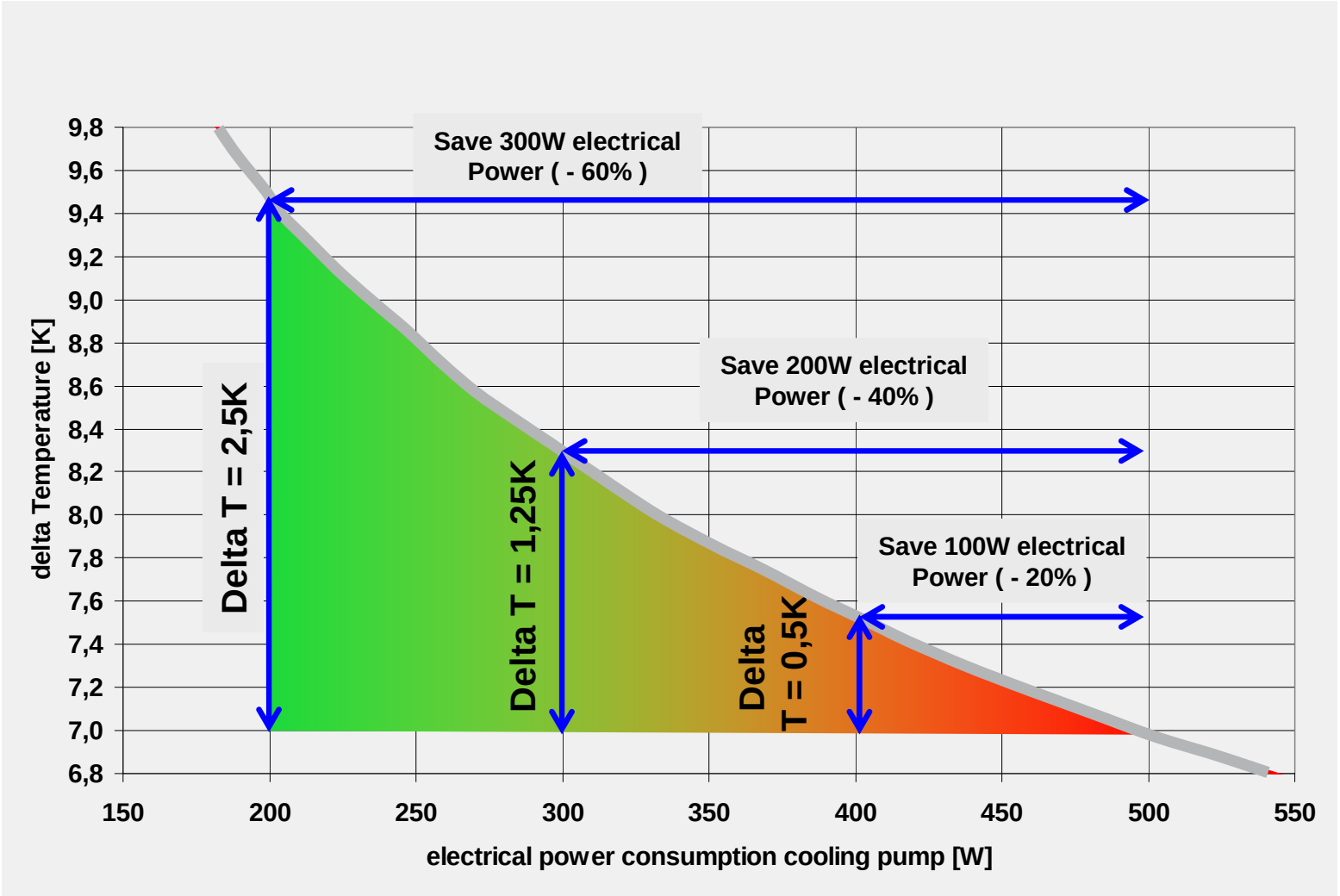
Influence cooling flow to delta temperature engine

Example values 96KW diesel engine

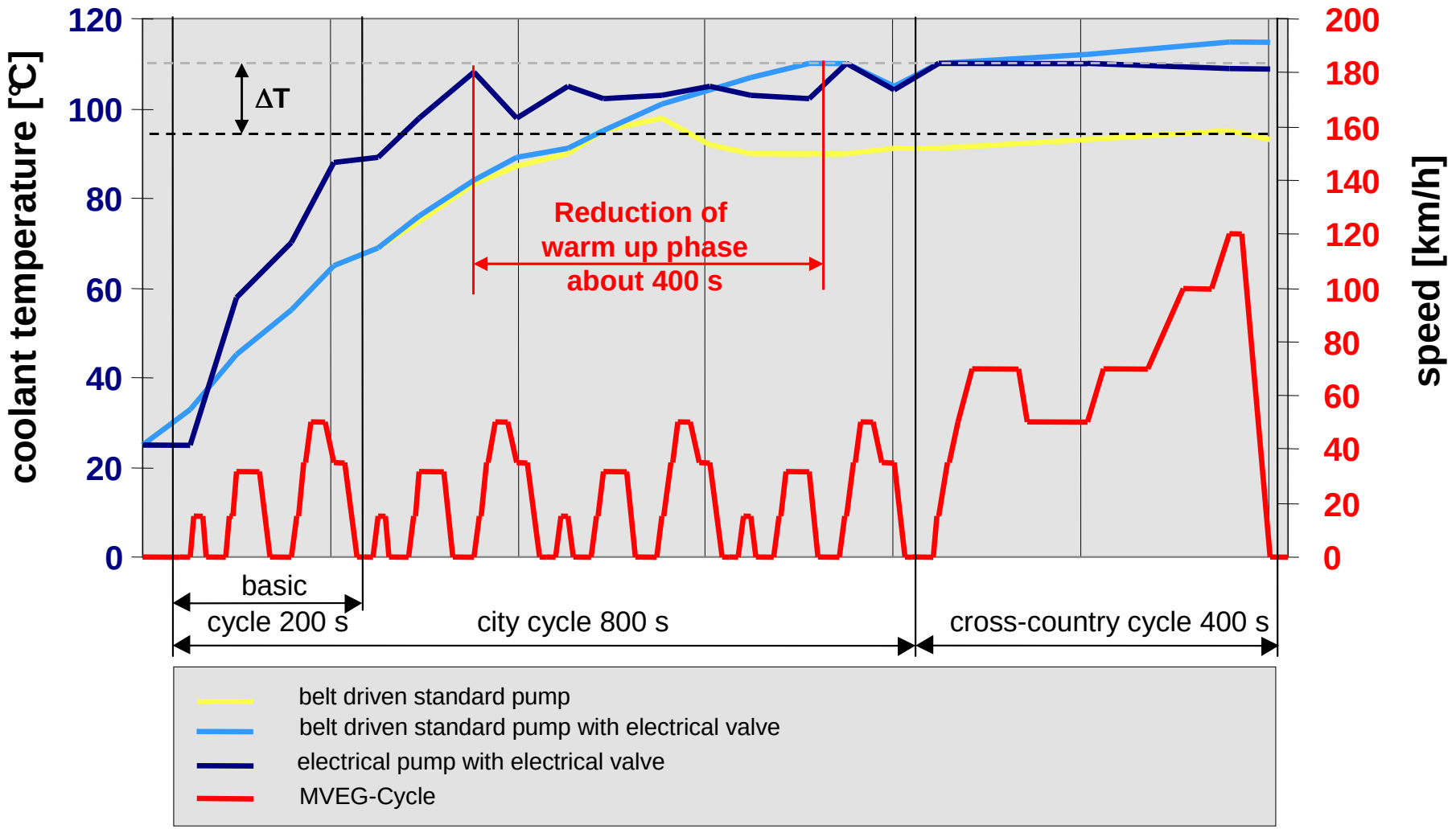


$$\dot{Q} = m \times cp \times (T\_out - T\_in)$$

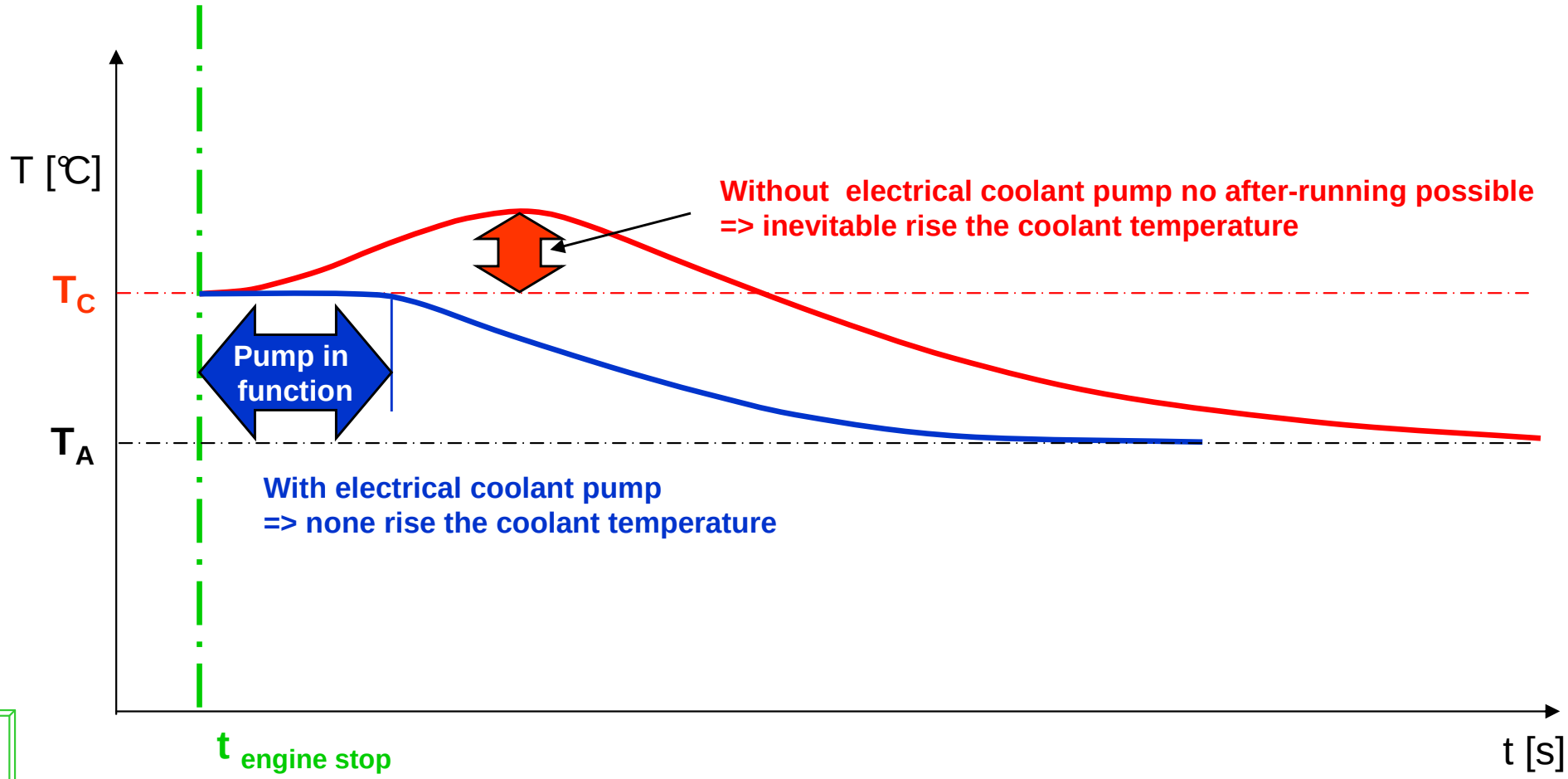
Delta temperature T_out – T_in (engine)



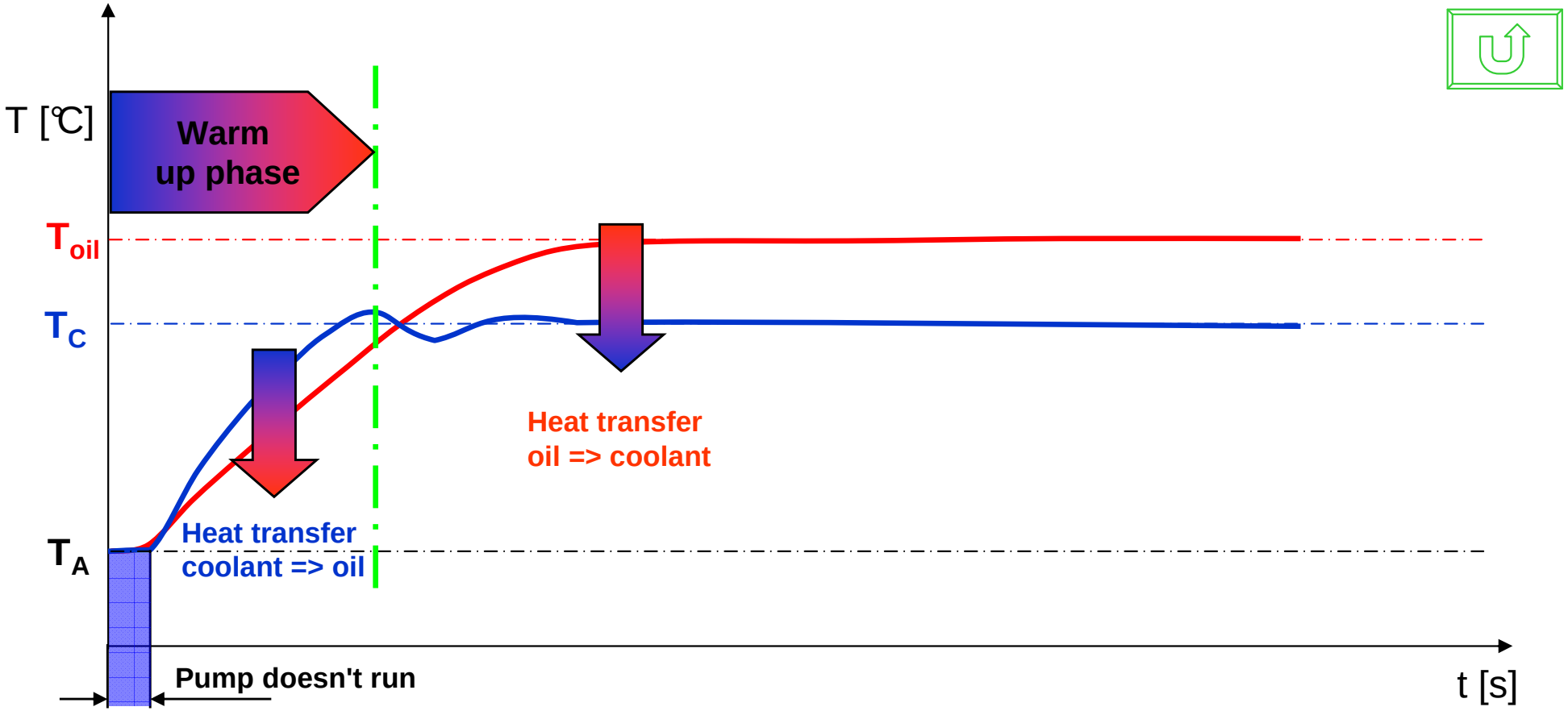
Comparison of the warm-up phases (4-cylinder engine) with mechanical and electrical coolant pump



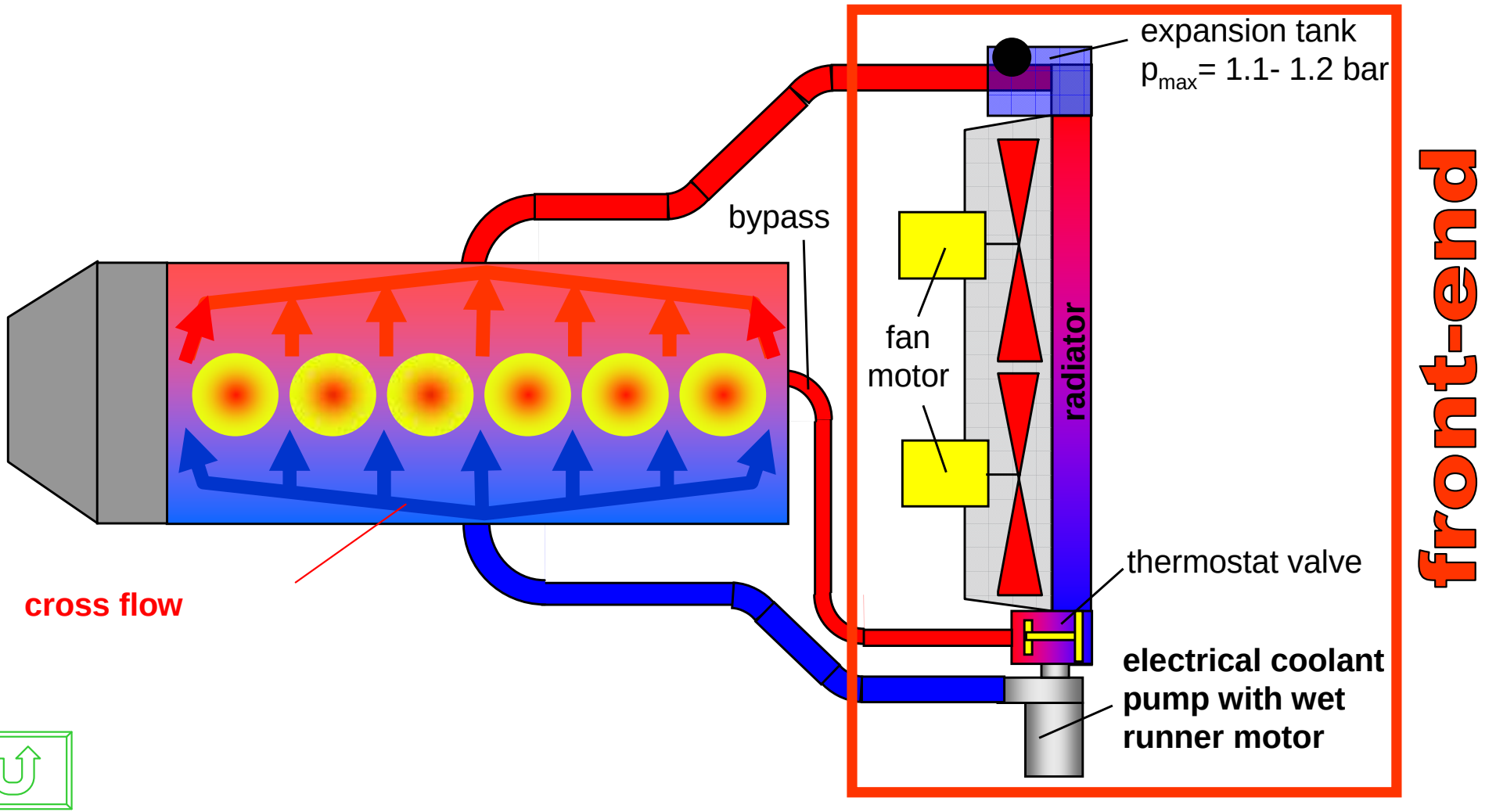
Avoidance of the temperature rise in the after-running phase



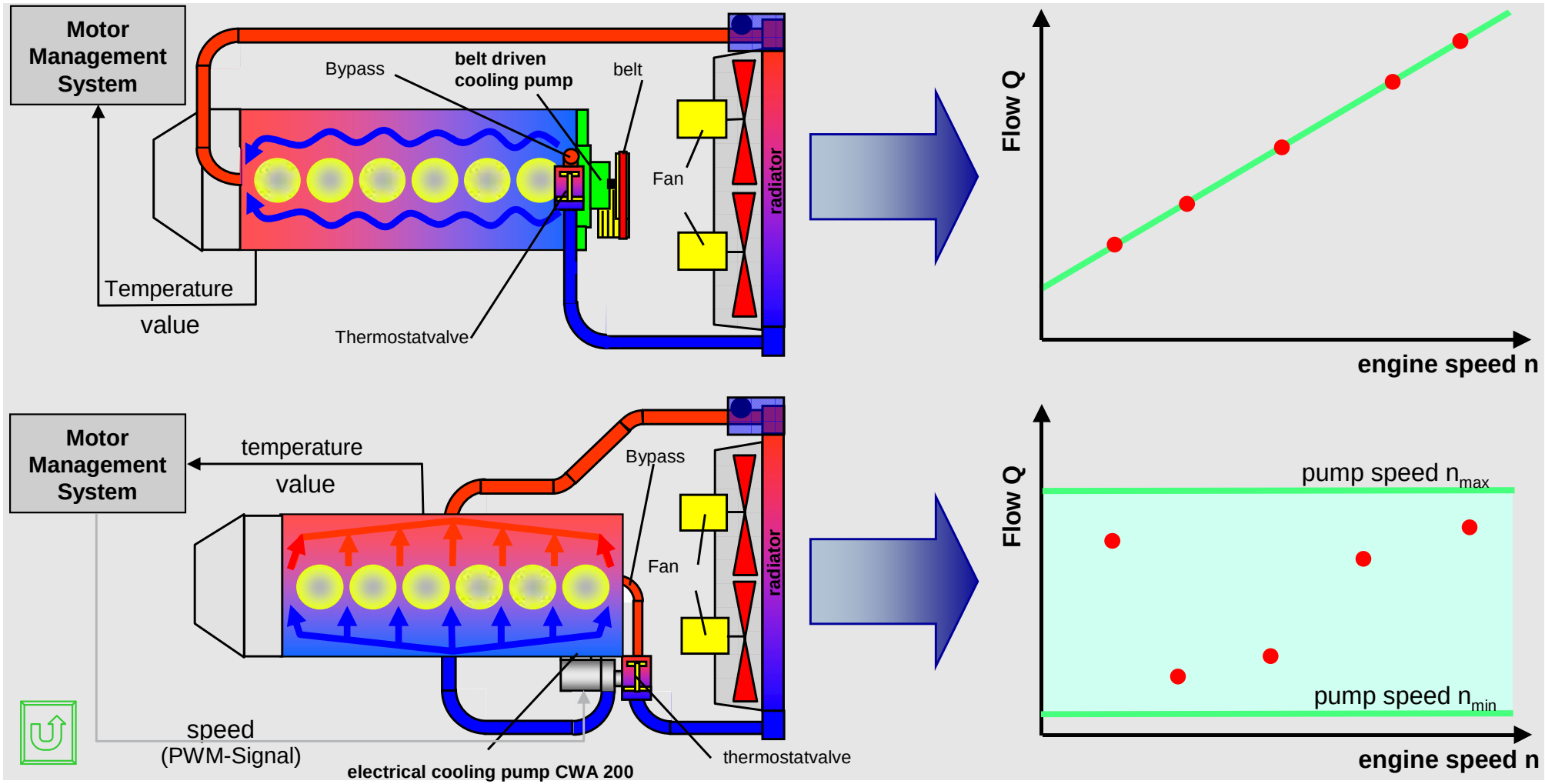
Faster warming of the oil after the cold start and cooling the oil at warm engine



Combustion engine with electrical driven coolant pump => Combination of all components in the FRONT-END



Comparison mechanical / electrical cooling pump



Possible strategies for control

performance air temperature

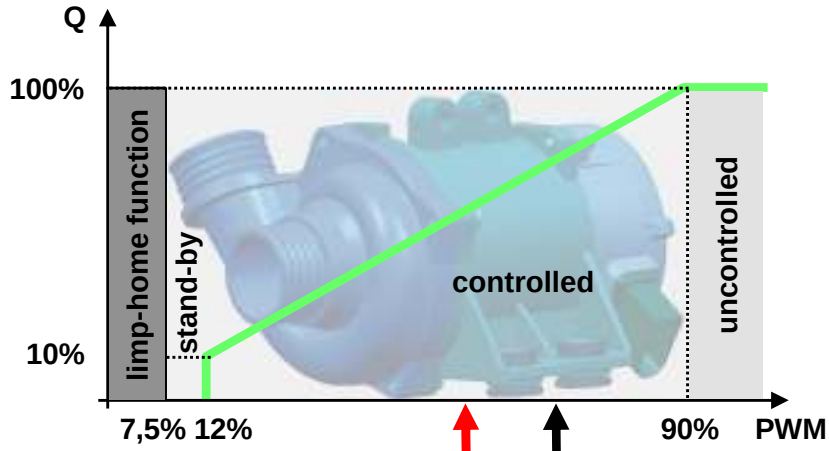
performance load

performance velocity

performance cabin heater

performance coolant-temperature

engine-control unit

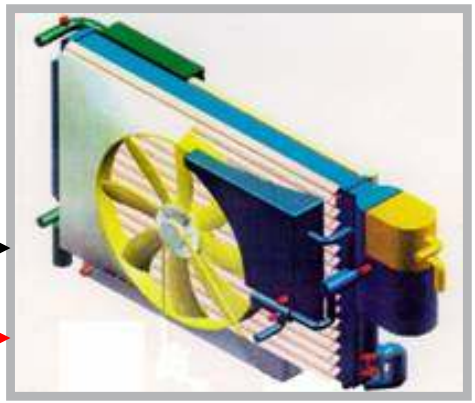


LIN-Bus

PWM-Signal

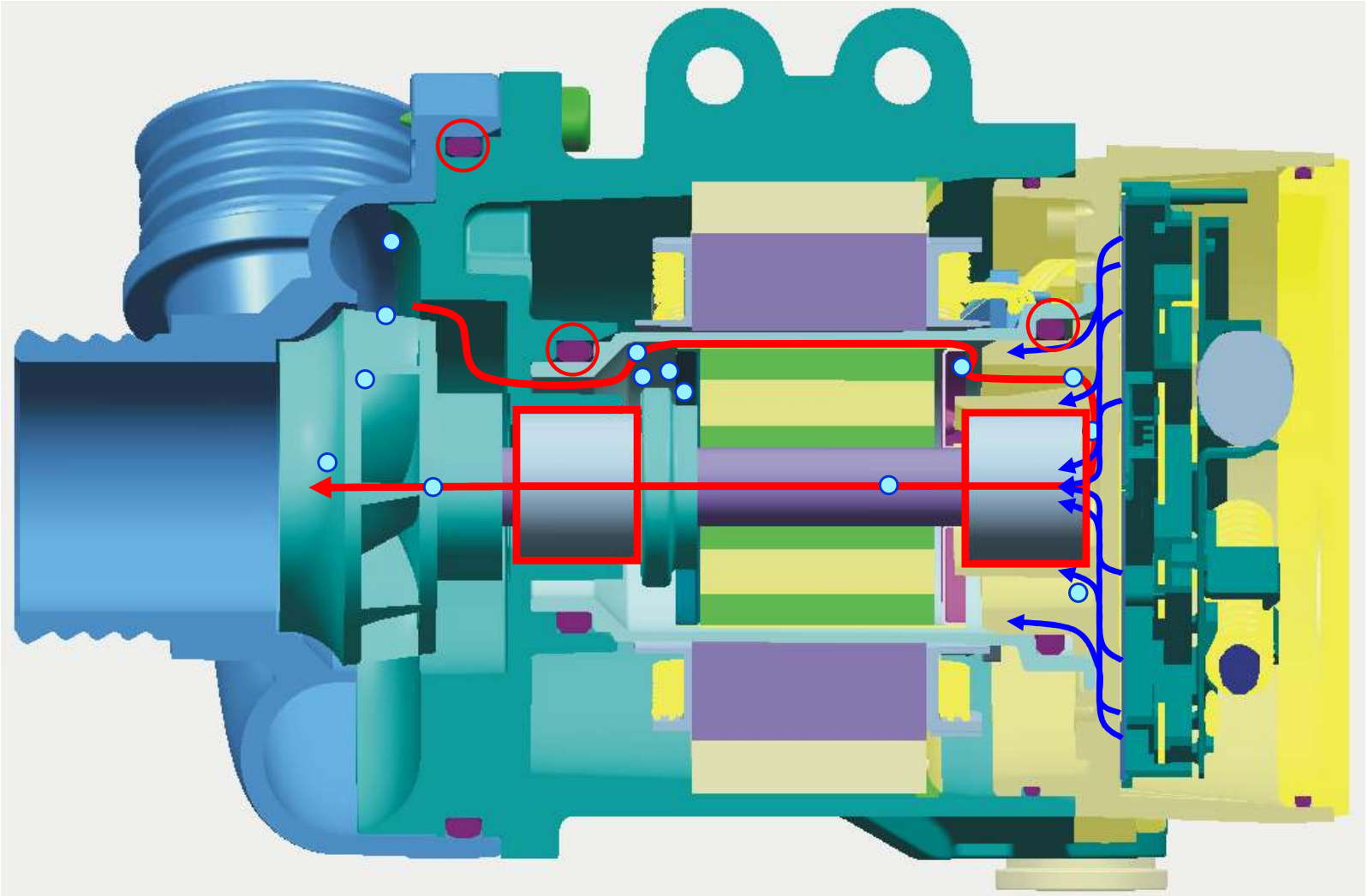
PWM-Signal

LIN-Bus

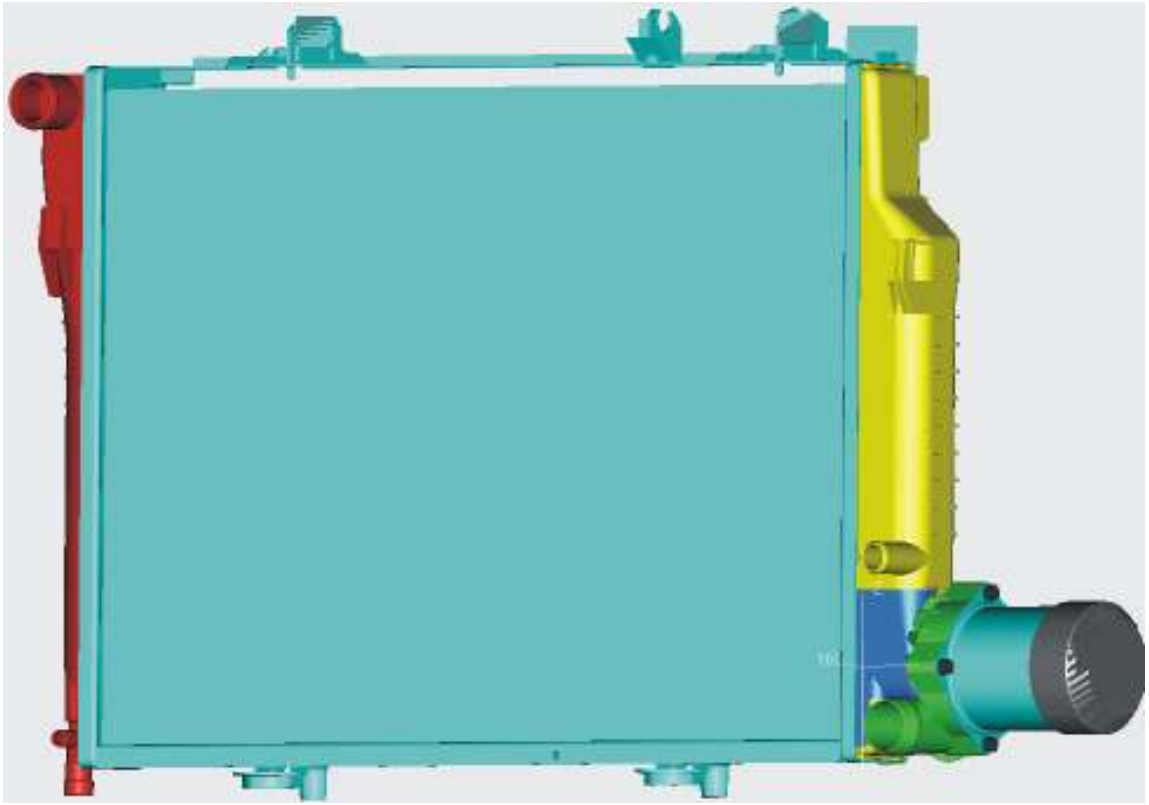


The electrical coolant pump CWA 200 with EC-Motor as wet runner

- **Only use of static seals**
- **Internel flow through pump:**
  - Lubrication of the gliding-surface bearings
  - Ventilation of rotor space
  - Cooling of the electronics (heat dissipation in the coolant)



The electrical coolant pump integrated in the front end



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Hydraulic: 3-D-Impeller

- **Special geometry**
  - ⇒ optimised flow
  - ⇒ better NPSH (Net Positive Suction Head)- value
  - ⇒ higher efficiency than the impeller with cylindrical blades
- **Lay-out data**
  - Q = 7 m³/h
  - H = 4,5 m
  - D_2 = 42 mm
  - n = 4500 min^{-1}
  - t_{max} = 128 ℃ (coolant)
  - Rate of mixture = 50/50 Water/Glycol

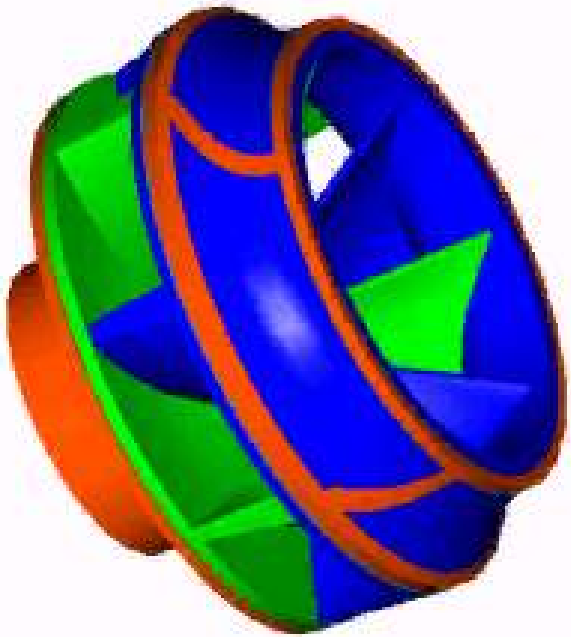
Hydraulic: 3-D-Impeller

- **Plastic * (PPS)**
  - ⇒ **less weight** than a metal impeller
  - ⇒ **profiled blades**
  - ⇒ **rounded entry edge**
  - ⇒ **smooth surface**

  - ⇒ **optimised cost** because of a new process of manufacturing

Hydraulic: 3-D-Impeller

- **new process of manufacturing**



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