PFEIFFER VACUUM

VACUUM FOR PARTICLE ACCELERATORS
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MECHANICAL VACUUM PUMPS

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Lecturer

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- Located in Asslar, Germany
- Product Manager for
  - Air cooled roots pumps
  - Roots pumping units
  - Dry screw pumps
  - Membrane pumps
  - Rotary piston dry pumps

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- Membrane (diaphragm) pumps
- Scroll pumps
- Turbomolecular pumps
- Multistage roots pumps
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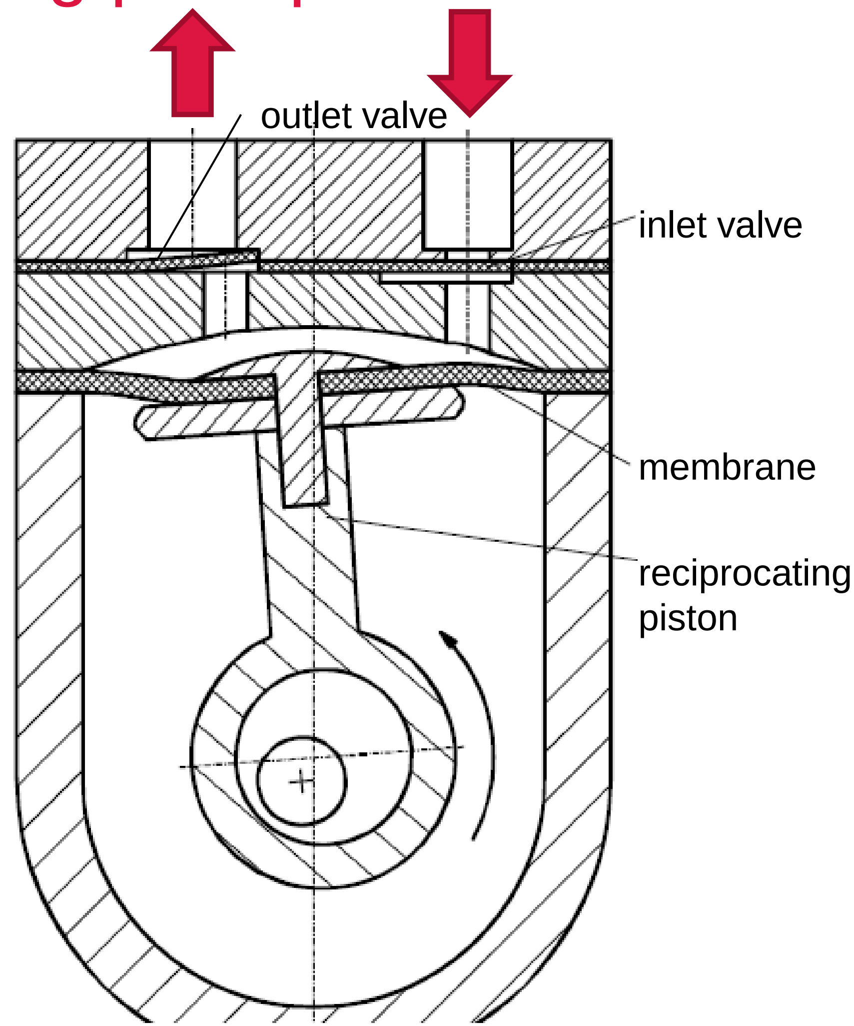
- Dry screw pumps
- Pumping units
- Pros & Cons of various pump principles
- Selection of mechanical pumps by application

MEMBRANE (DIAPHRAGM) PUMPS

Membrane pumps – working principle

- Membrane is moved back and forth by means of a reciprocating piston drive
- Working principle
  - During the suction step the membrane fills the pump room with gas. The exhaust valve is closed
  - During the exhaust step the membrane compresses the gas towards atmosphere. The inlet valve is closed



Animation_Membranpumpe.mp4

Membrane pump versions

- AC and DC (24 V) motor versions
- Double (2) up to quadruple (4) head pump versions on the market
- The heads can be connected in different ways
  - 2 – head version
    - Heads in parallel for high pumping speed
    - Heads in series for low ultimate vacuum
  - 3 – to 4 – head version
    - 3 stages, where 2 heads are in parallel for best pumping speed / ultimate vacuum ratio
    - 4 heads in series for low ultimate vacuum

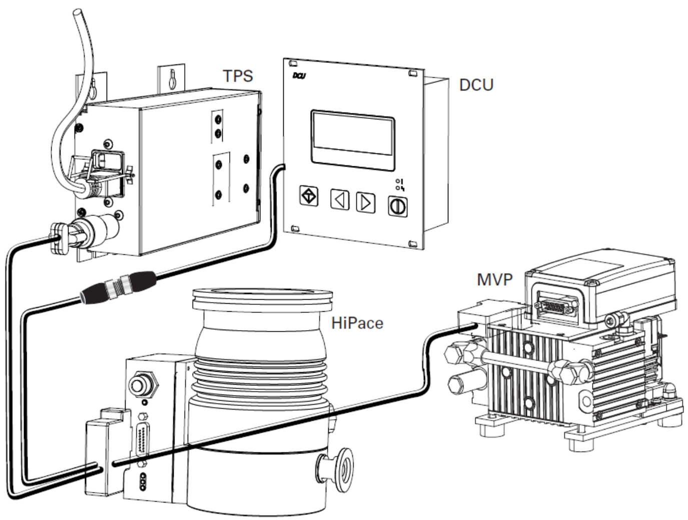
Membrane pumps in 24 V DC

- 24 V DC – motor
  - One power supply can be used in combination with turbomolecular pumps, diaphagm pump can be directly connected to the turbo remote connector.

Advantage	Customer benefit
▪ Low voltage	▪ Lower safety requirements
▪ Reduced footprint	▪ Easy system integration
▪ Reduced weight	▪ Improved mobility
▪ No fan, very quiet	▪ Noise level < 50 dB (A)
▪ Low power consumption	▪ Low cost of ownership (CoO)

Membrane & turbo pump integration (Pfeiffer)

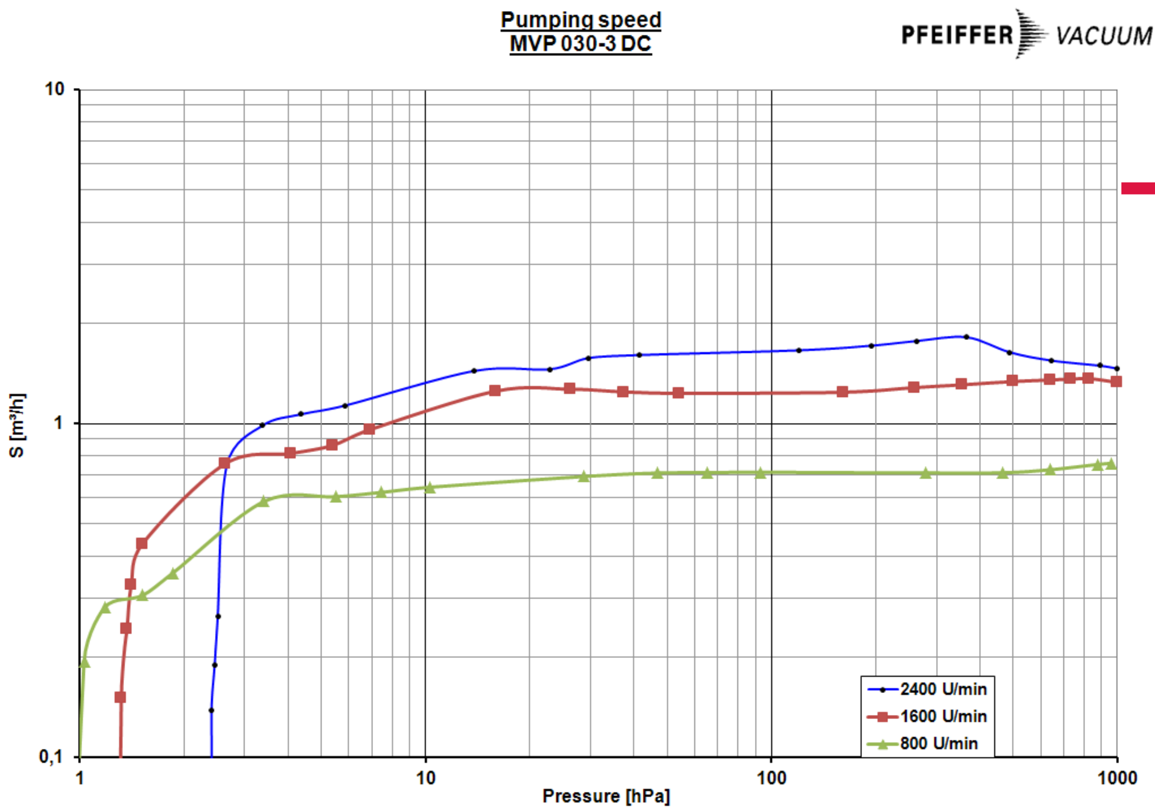
- Unified communication – 15-pin D-Sub



Feature	Advantage	Customer benefit
RS 485	▪ Similar set of parameters like TMP ▪ One standard for all Pfeiffer products ▪ Communication with TMP	▪ Control via SPS possible ▪ Easy system integration ▪ Complete vacuum solution
D-Sub interface (15-pin D-Sub)	▪ Power supply & communication via one interface	▪ Low integration cost for cabling

Membrane pumps (DC) with variable speed control

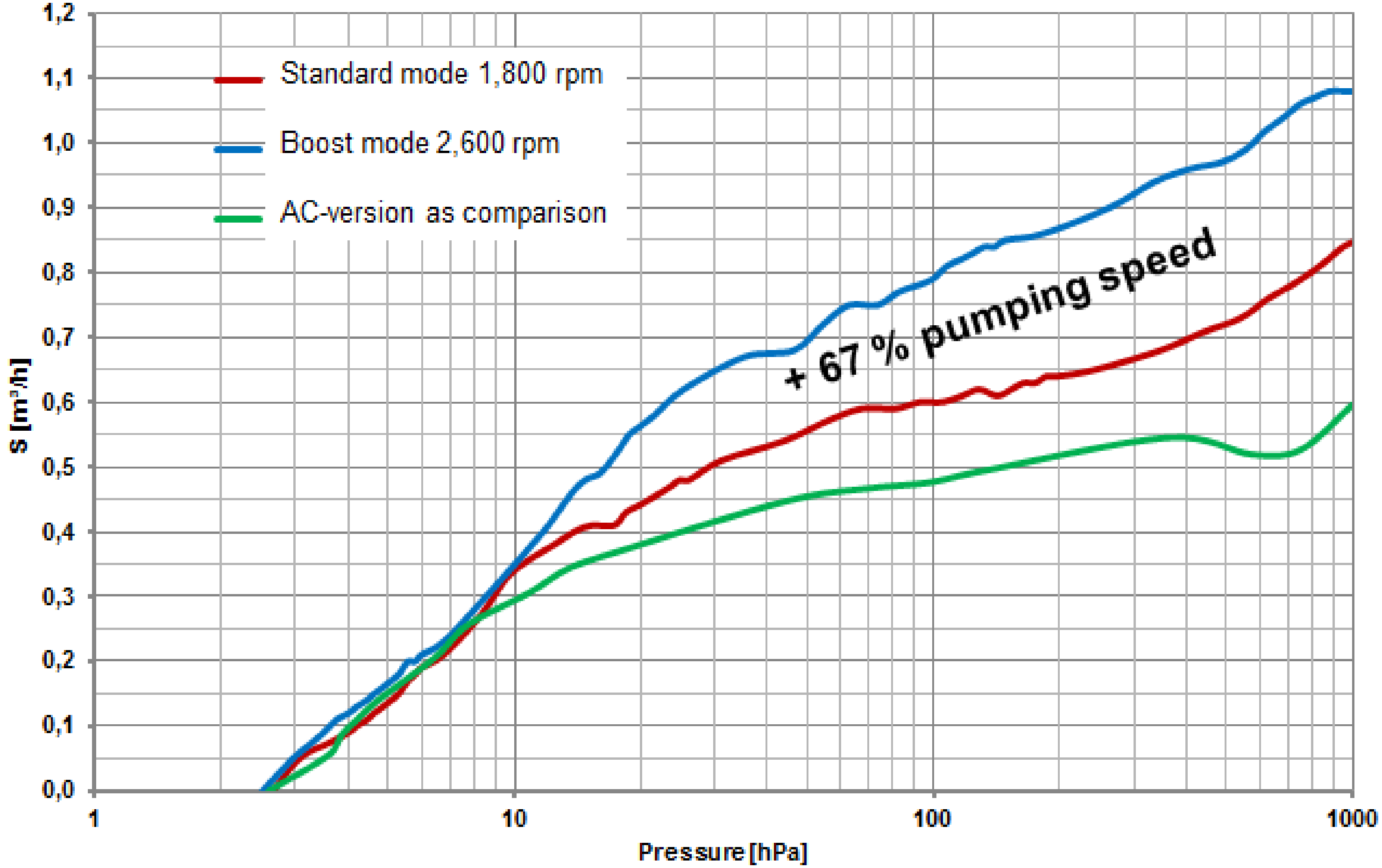
- Variable speed modus



Intelligent control of the MVP allows optimization of pumping speed and ultimate vacuum depening on application

Speed controlled operation modus TC 110

MVP 015-2 DC – Vacuum Performance



Mmembrane pumps for turbomolecular pumps

Overview

	MVP 030-3	*MVP 015-4*	*MVP 015-2*	*MVP 010-3*
Weight	4,3 kg	4,4 kg	2,7 kg	2,05 kg
Volume	5,2 dm^3	4,5 dm^3	3,4 dm^3	1,9 dm^3
Pumping speed	1,8 m^3/h	0,75 m^3/h	1 m^3/h	0,6 m^3/h
Final pressure	2,5 hPa	0,5 hPa	3,5 hPa	1 hPa

Highest Performance

Lowest final pressure

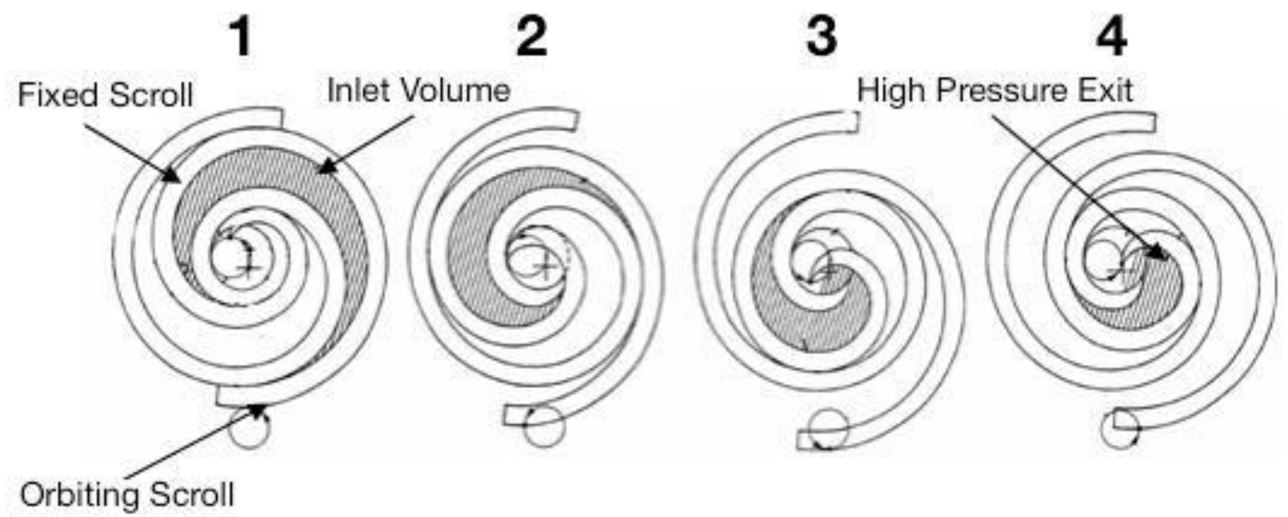
General purpose

Most compact and lightweight

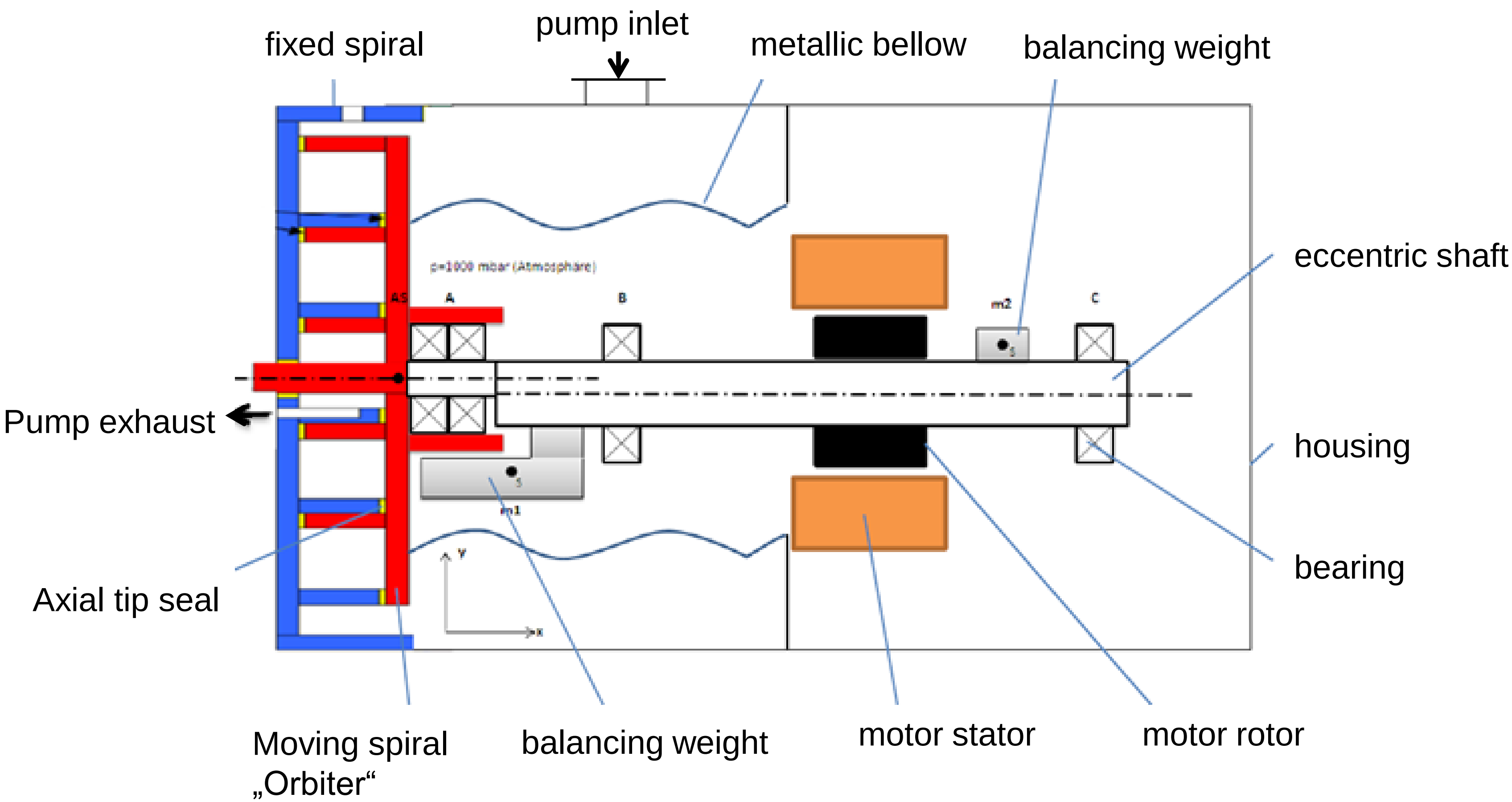
SCROLL PUMPS

Scroll pump working principle

- Excentric moving orbital scroll rotor
  - 1 – inlet volume
  - 2 – 4 compressing to atmosphere



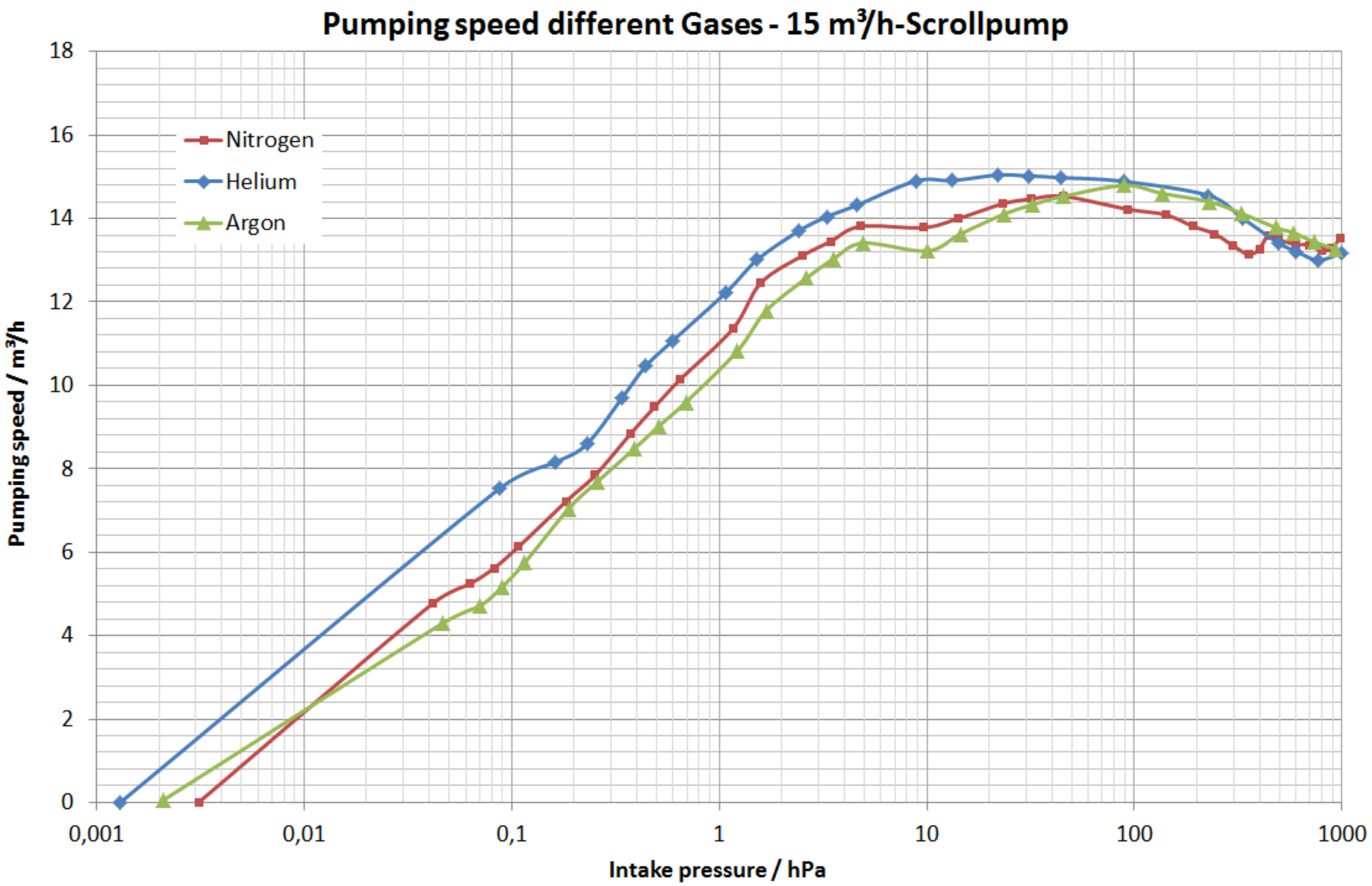
Scroll pump design



Scroll pumps features

- Advantages
  - Simple design
  - Small pumps as backing pumps for low gas throughputs
  - Ultimate vacuum < 10^{-2} hPa
  - Quiet < 55 dB (A)
  - Low initial cost

Scroll pump – performance with different gases



Scroll pumps

- disadvantages
  - Tip seal wear requires regular seal change
  - Generates particles at inlet and exhaust side
  - With increasing tip seal wear performance regarding pumping speed and ultimate vacuum will be reduced
  - Automatic non return valve on inlet side required

Scroll pump performance limitations

- Nearly gas independent pumping characteristic
- Limited water vapour capacity (gas ballast)
- Generation of particles due to tip seal wear
- Short service intervals due to tip seal change
  - Tip seal change kit ca. 300 – 400 €
  - Overhaul > 1,000 €

TURBOMOLECULAR PUMPS

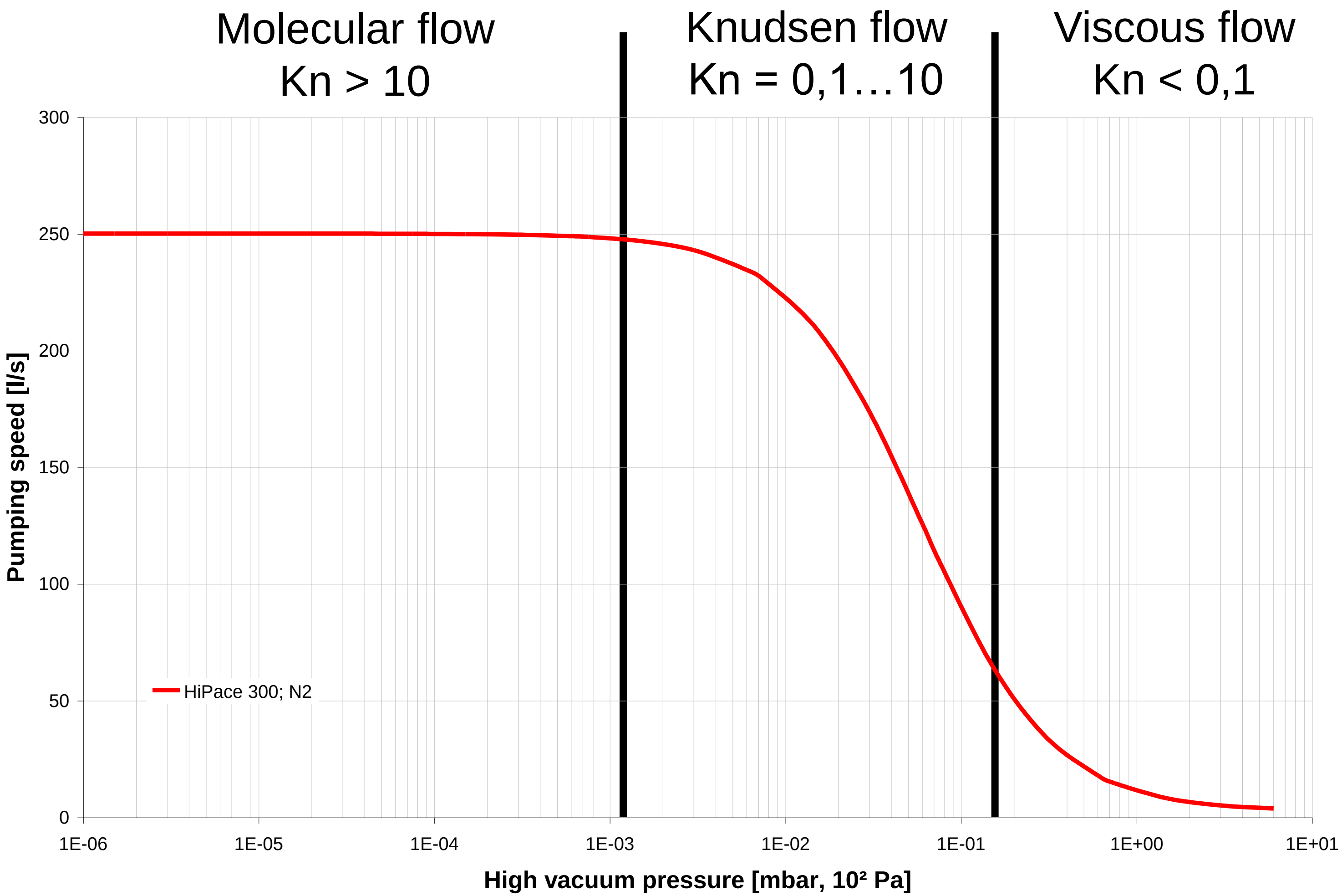
Turbomolecular pump definition

- The turbopump or turbomolecularpump
is a high vacuum pump (backing pump required)

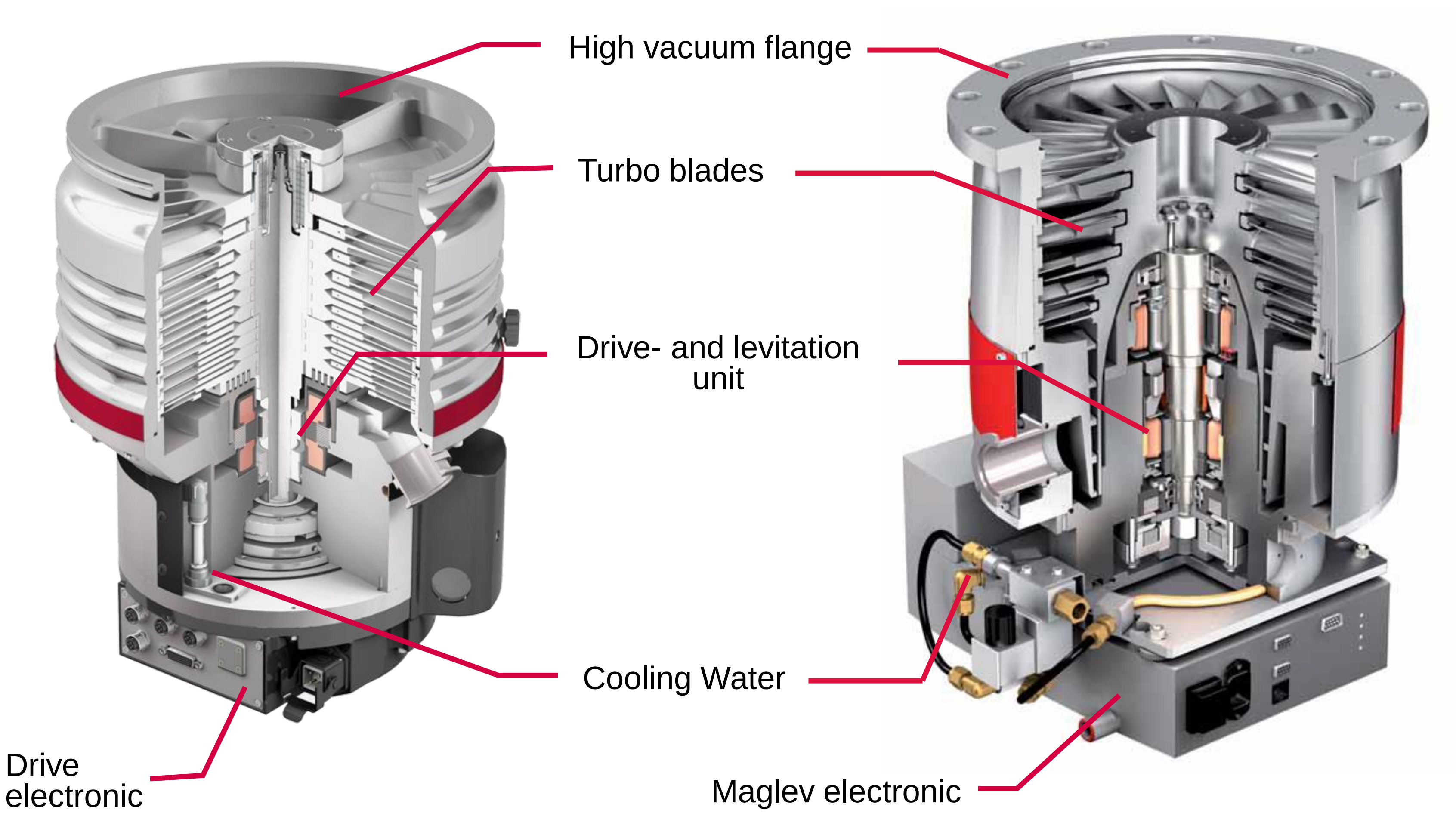
- The turbopump is a momentum transfer pump

- Gas molecules can be given momentum in a desired direction by repeated collision with a moving solid surface.

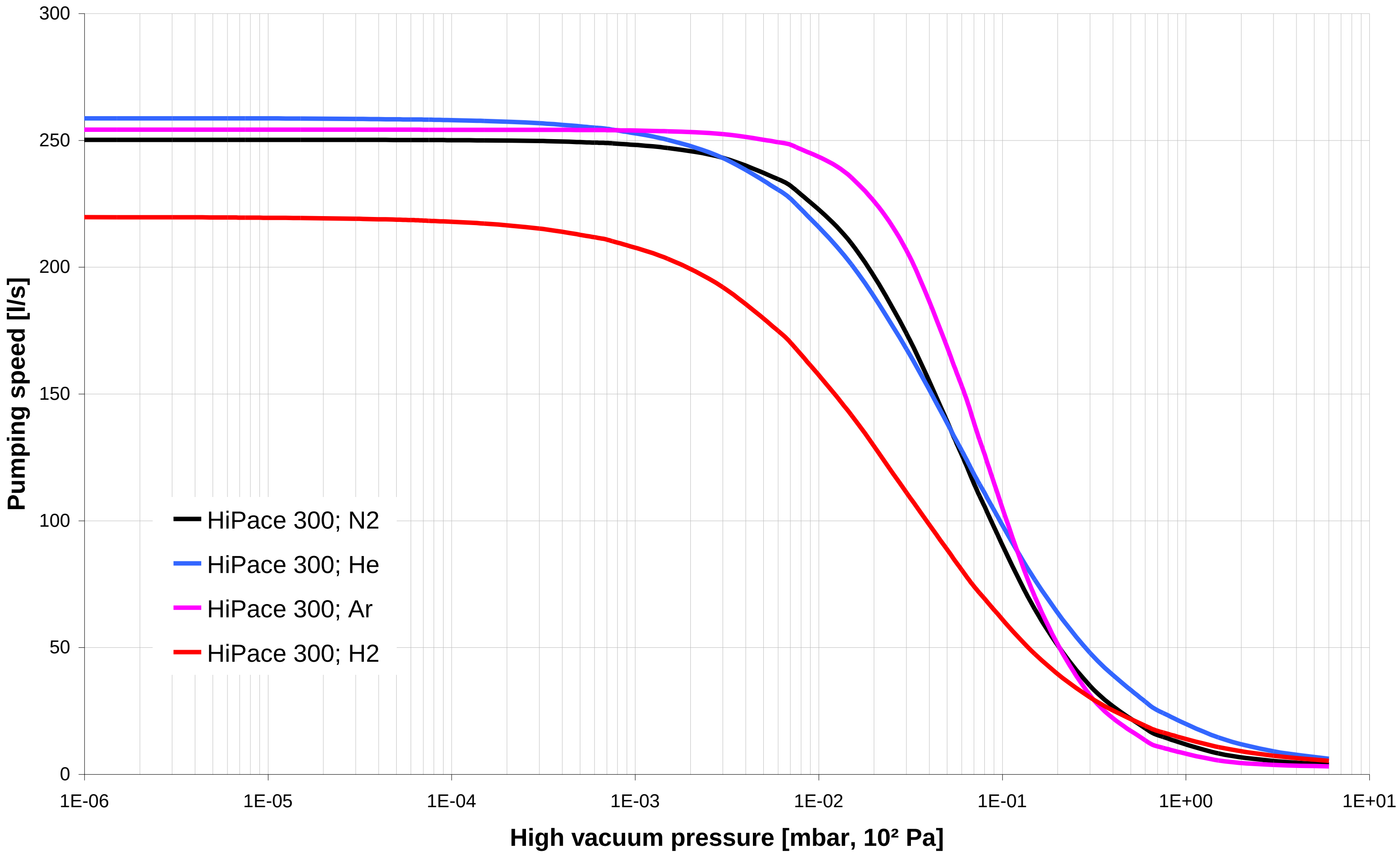
Different Flow Areas



Turbopump Design



Gas type dependant pumping speed



Different Rotor Concepts

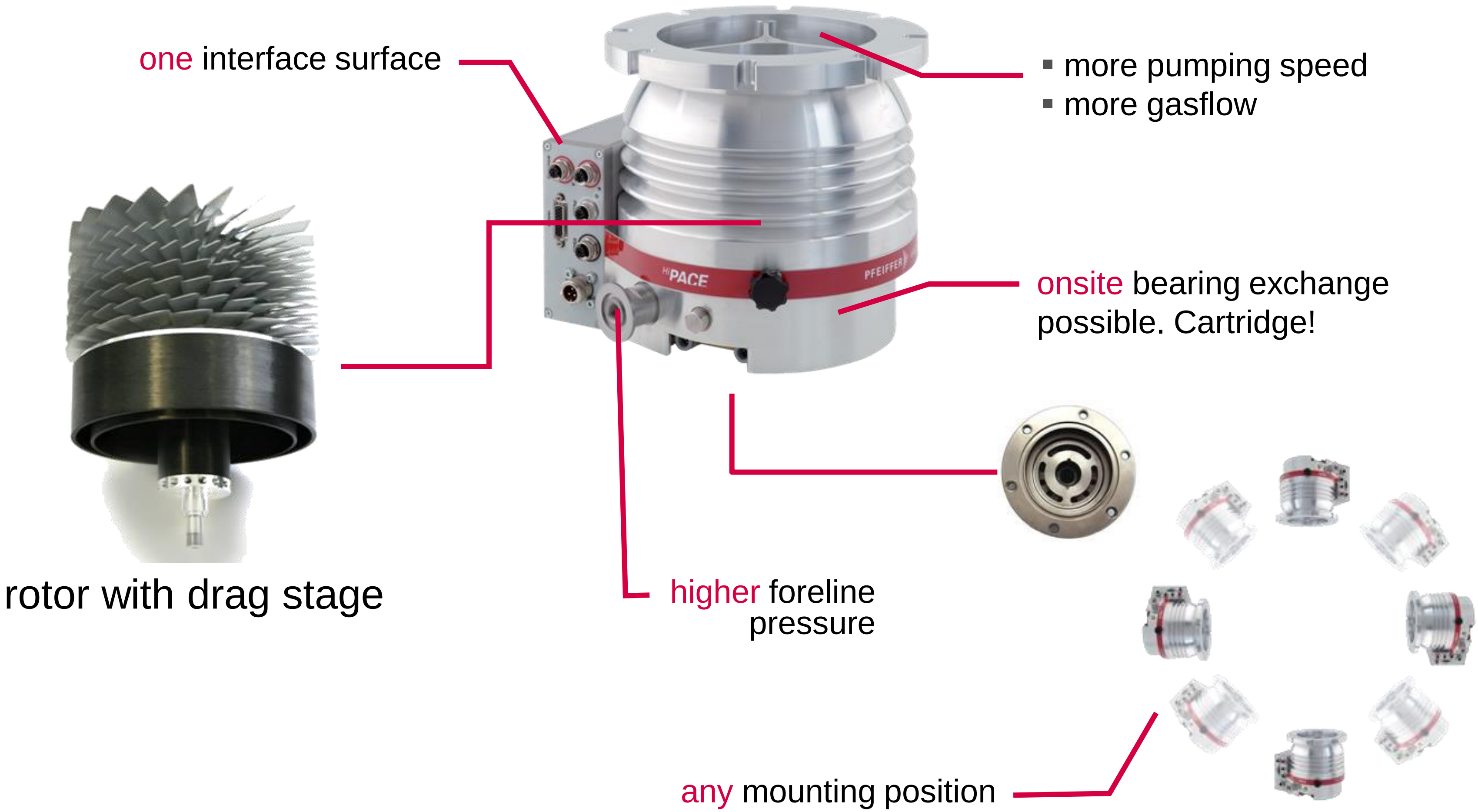
With Holweck Stage

- Compression optimized
- Ultra High Vacuum

Pure Turbo

- Gas flow optimized
- Suitable for process applications

Pumping Speed 10 to 700 l/s



HiPace 300 H - Features

- Highest compression ratio especially for light gases
- Creates ultra low residual gas backgrounds
- Ideal for HV- and UHV applications
- Best UHV pressures even in combination with diaphragm pumps
- With MVP015-4 DC backing pump < 10^{-10} hPa
- Intermittent mode reduces energy consumption up to 90 %
- Target group: R&D and Analytic customers

HiPace 300 H

Technical features

- Highest compression especially for light gases (10^7 for H_2)
- Outstanding max. fore-vacuum pressure

Customer benefits

- Best ultimate pressures, ultra low residual gas background, ideal for mass spectrometry applications
- Best UHV performance even in combination with diaphragm pumps
- Intermittent mode reduces the energy consumption of the overall vacuum system by more than 90 %

Turbomolecular pumps in radiation environment

- Pfeiffer Vacuum HiPace 80, 300, 800
  - Unique Concept with remote power supply TCP350
  - Cable length between pump and power supply
    - HiPace 80 & 800 up to 250 m, HiPace 300 up to 1,000 m
- Realized at CERN in Large Hadron Collider (LHC)

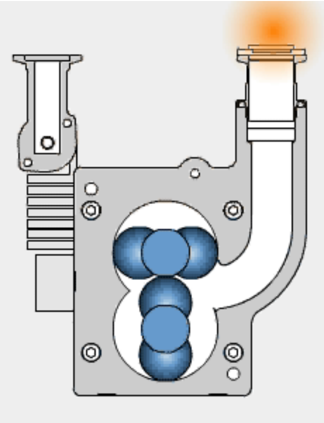
HiPace 300

Cable HiPace-TCP350

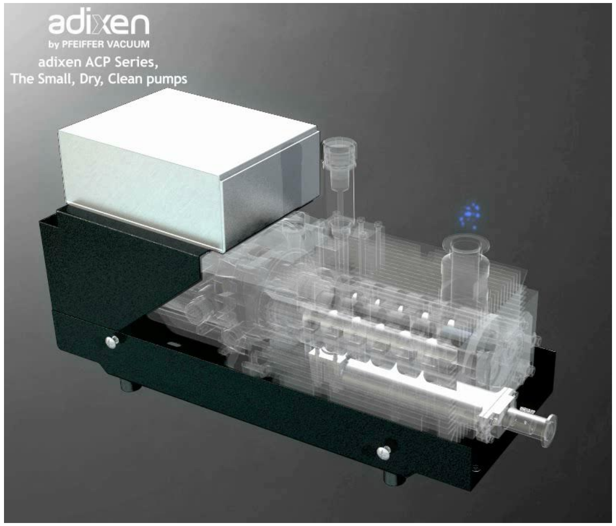
TCP350

MULTISTAGE ROOTS PUMPS

Multistage roots pump



- Functional principle
  - No contact between rotor and stator
  - No mechanical load of seals in the pump cavity
  - Multistage design up to 8 stages
  - Ultimate vacuum < 10^{-2} hPa
- Executions
  - Standard
  - With gas ballast for pumping vapours
  - Corrosive version for corrosive traces
  - remote electronics for radiation environment



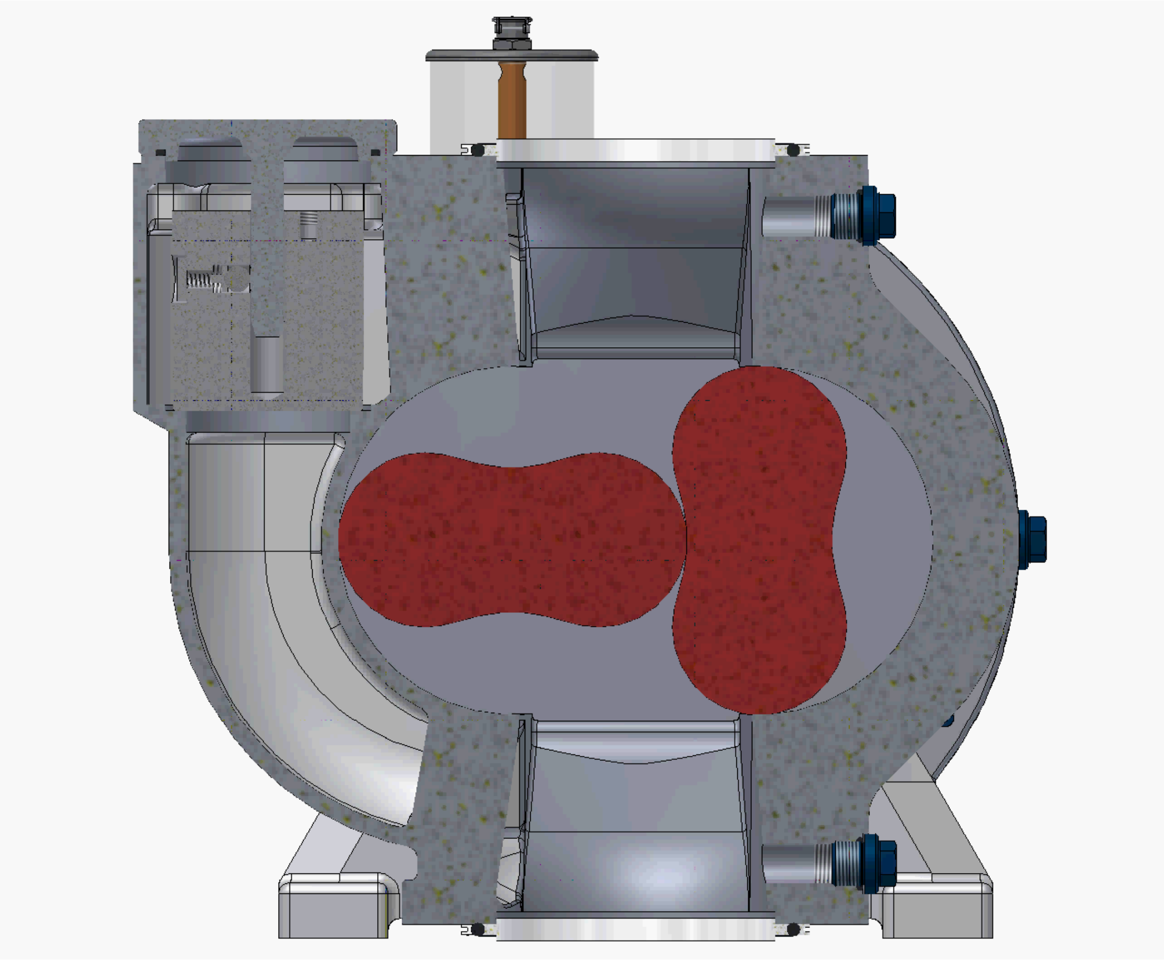
ROOTS PUMPS

Roots pumps

- Invented by the Roots brothers in 1865 to blow air to fire up steel melting furnaces
- Top performance/size ratio
- Used up to ultimate vacuum > 10^{-4} hPa
- Available in sizes from 150 – 97,000 m^3/h
- Normally with shaft seals
  - One supplier offers magnetic coupling
- Bypass valve
  - for thermal overload protection
  - Switching on at atmospheric pressure

OktaLine 2000 M Film EN.mp4

Roots pumping principle



Roots pump working principle

- Phase 1

  gas inlet on HV-side

- Phase 2

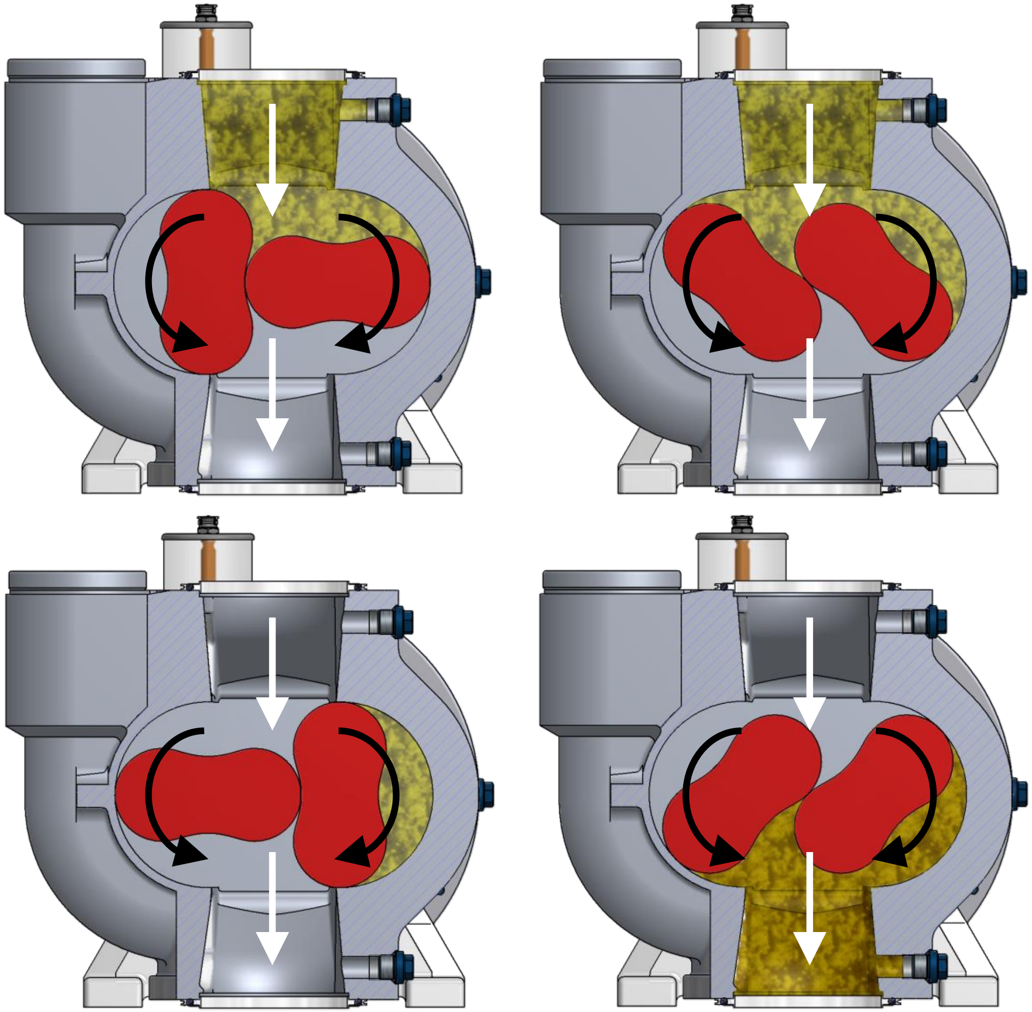
  gas flows in until volume is closed

- Phase 3

  gas moved to FV-side

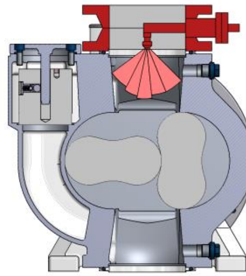
- Phase 4

  gas outlet and compressed to FV-pressure

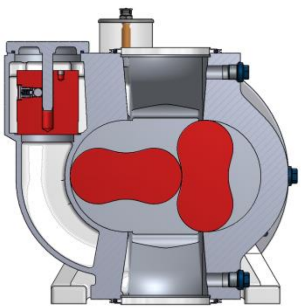


Roots pump features and *optional accessories

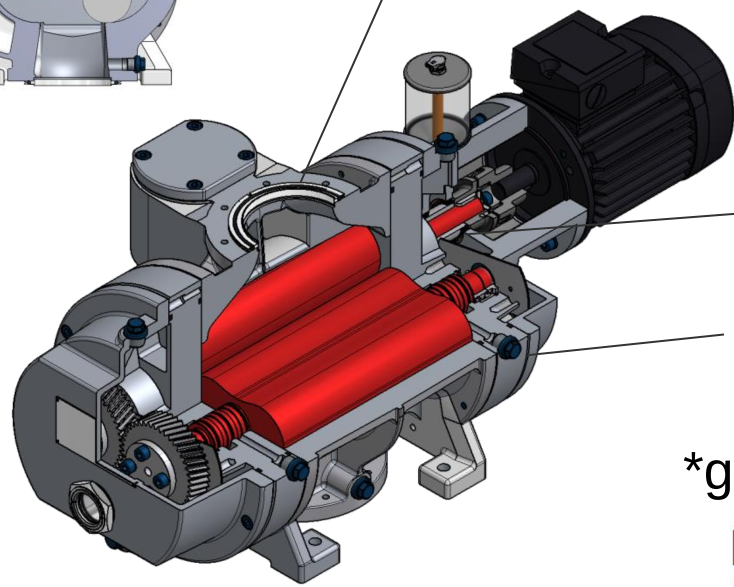
*flushing device



overflow valve



standard connections
DN ISO-F/PN16

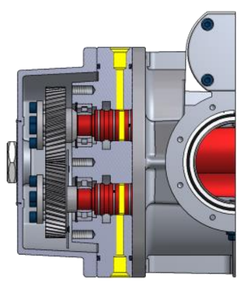


standard motor

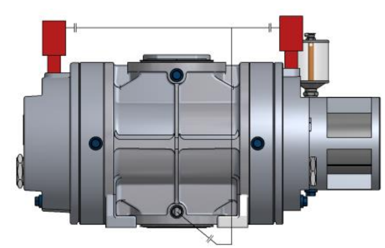
seals made of FPM

measuring ports

*sealing gas kit



*gear box extraction kit



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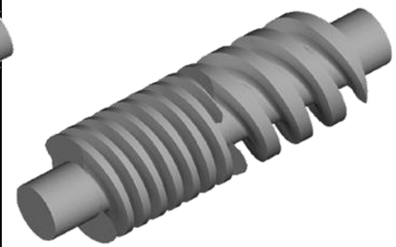
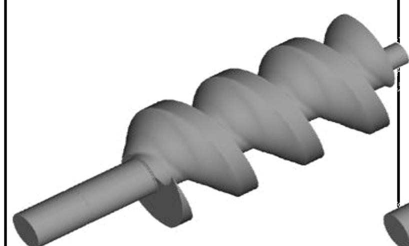
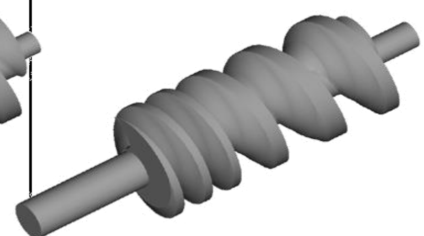
DRY SCREW PUMPS

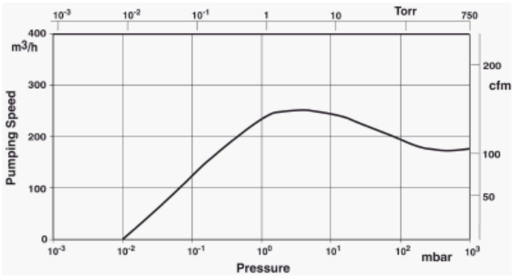
Screw pumps – screw rotor types

	Constant pitch	Variable pitch	Characteristics
Symmetrical profiles			+ : simple calculation and manufacturing -: low performance!
Asymmetrical profiles			-: complex calculation and manufacturing +: best performance!

Dry screw pump – advantages / disadvantages

- Advantages
  - Dry compression
  - High pumping speeds 50 – 2,000 m^3/h
  - Durable, tolerant to particles and vapours
  - Dry forevacuum pump for roots pumping units
- Disadvantages
  - ~ 50 % reduced pumping speed for light gases
  - Silencer required
  - High gas temperatures
  - Low atmospheric pumping speed, slow pumping down

Technical Drawing



PUMPING UNITS

Pumping units

- with 2-stage RVP/Roots pump
  - ultimate vacuum < 5 x 10^{-4} hPa

- with 1-stage RVP/Roots pump
  - ultimate vacuum < 3 x 10^{-2} hPa

- with dry pump/Roots pump
  - ultimate vacuum < 1 x 10^{-3} hPa

- With dry pump/turbomolecular pump
  - membrane, scroll, multistage roots pump
  - Ultimate vacuum up to < 1 x 10^{-10} hPa

with membrane pump

with multi stage Roots pump

Pumping units

- Standard pumping unit program with membrane, scroll, multistage roots, dry screw pumps in combination with Roots and turbomolecular pumps on the market
- Customized pumping units per specification can be realized by the main vacuum pump suppliers
  - Special units for Helium 4 or Tritium can be provided as joint development with the R&D community like ITER

PRO & CONS FOR VARIOUS VACUUM PUMP PRINCIPLES

Pros & Cons for varous pumps principles

Features	Rotary vane pump	Membrane pump	Piston pump	Scroll pump	multistage Roots pump	Roots pump	dry Screw pump
oil free	-	+	+	+	+	+	+
particle emmission	o	o	o	-	+	+	+
stability pumping speed/ultimate vacuum	+	o	o	-	+	+	+
reliability (magnetic coupled)	+	+	o	o	+	+	+
service intervals	o	o/+	o	o	+	+	o
initial cost	+	+	o	+	o	+	o
Total cost of ownership (TCO)	+	+	o	o	+	+	o

SELECTION OF MECHANICAL PUMPS BY APPLICATION

Selection of mechanical pumps by application

Requirement	Rotary vane pump	Membrane pump	Piston pump	Scroll pump	multistage Roots pump	Roots pump	dry Screw pump
radiation e.g λ, β, ϒ, neutron ray, ionized ray	+ (standard motor)	+ (standard motor)	+ (standard motor)	+ (standard motor)	+ (standard motor)	+ (standard motor)	+ (standard motor)
particle emmission	o	-	o	-	+	+	+
flourine free	-	-	-	-	+ (special version)	+ (magnetic coupled)	-
hydrocarbon free	-	+	+	+	+	+	+
remote electronics, long cables	+ (no electronics)	+ (no electronics)	+ (no electronics)	-	+ (electronics remoted)	+ (no electronics)	+ (no electronics)
material activation due to radiation	+	+	o	+	+ (pump system made of aluminum)	-	-

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