Dry Pump Technology

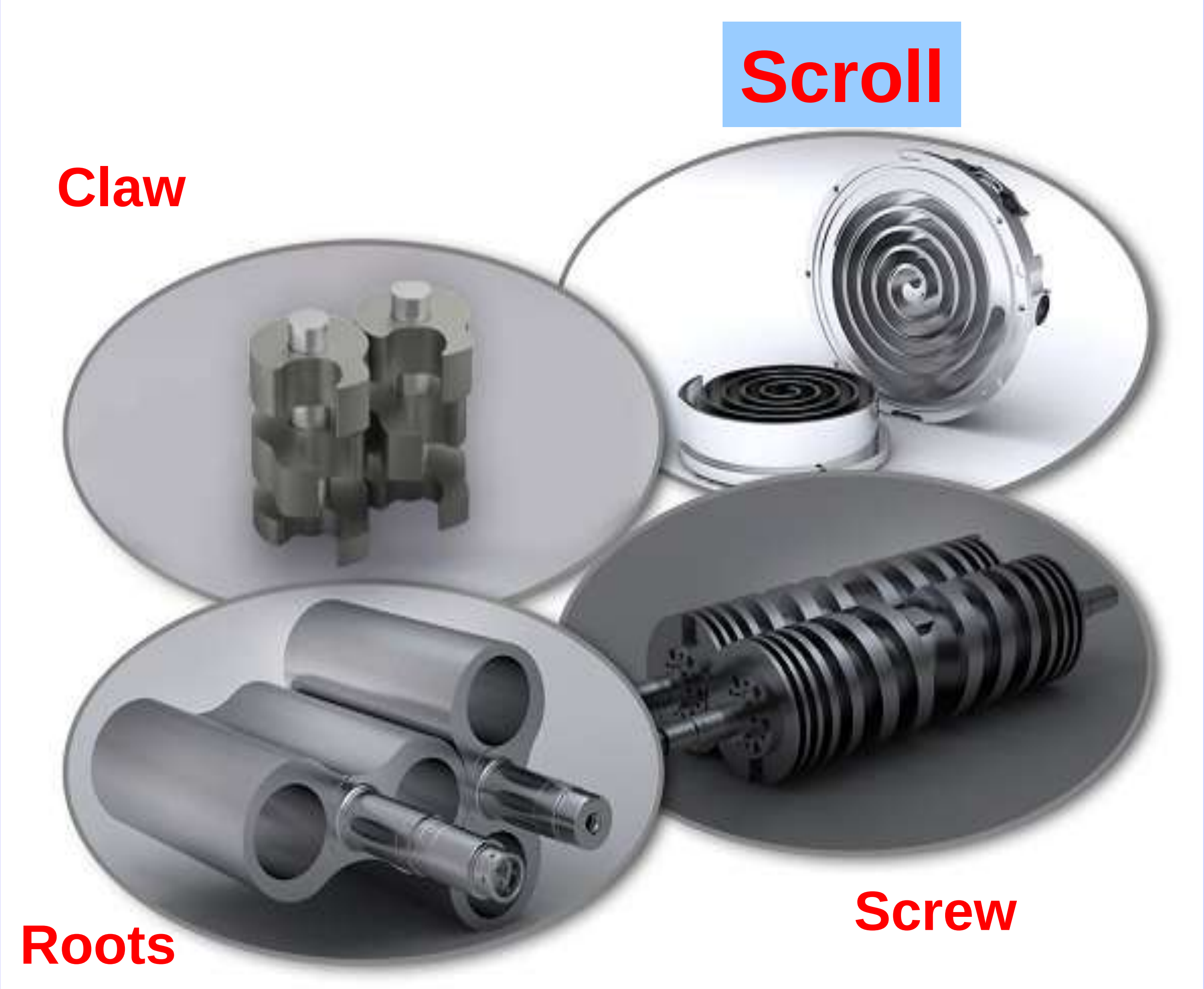
R Gordon Livesey

Dry Pumping

- No oil backstreaming into process chamber
- No contamination of process stream
- Effluent/waste disposal costs reduced or eliminated
- Lower maintenance costs
- Tolerant to heat load
- Lower utility costs

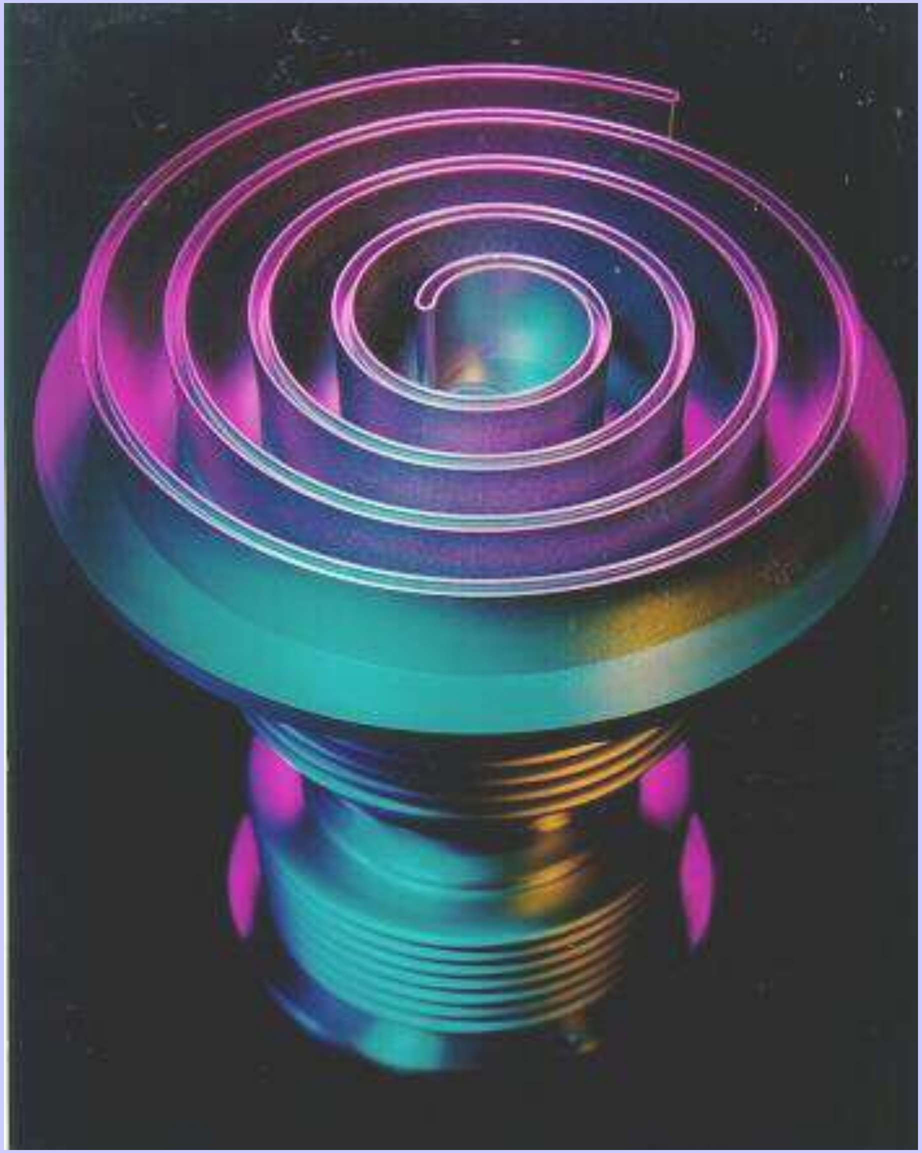
- Solvent recovery
  - Flavours, perfumes, fuel vapours
- Deodorization
- Evaporation/distillation
- Drying
  - Brake fluid, oils
- Desorption
- Seawater deaeration
- Steel degassing
- Semicon processes
- UHV

Dry Pump Technologies

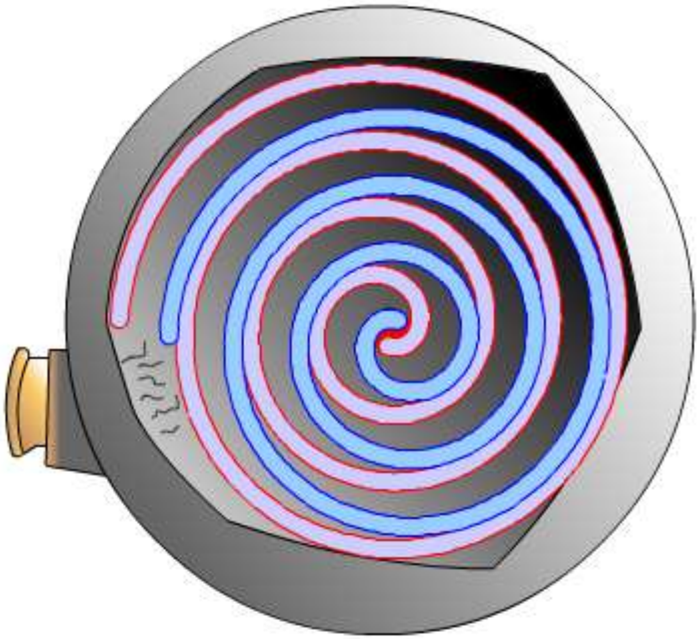


Scroll Pumps

- Comprises two opposing scrolls
- One scroll is fixed and the other orbits
- Each has a seal in the scroll end



Scroll Mechanism



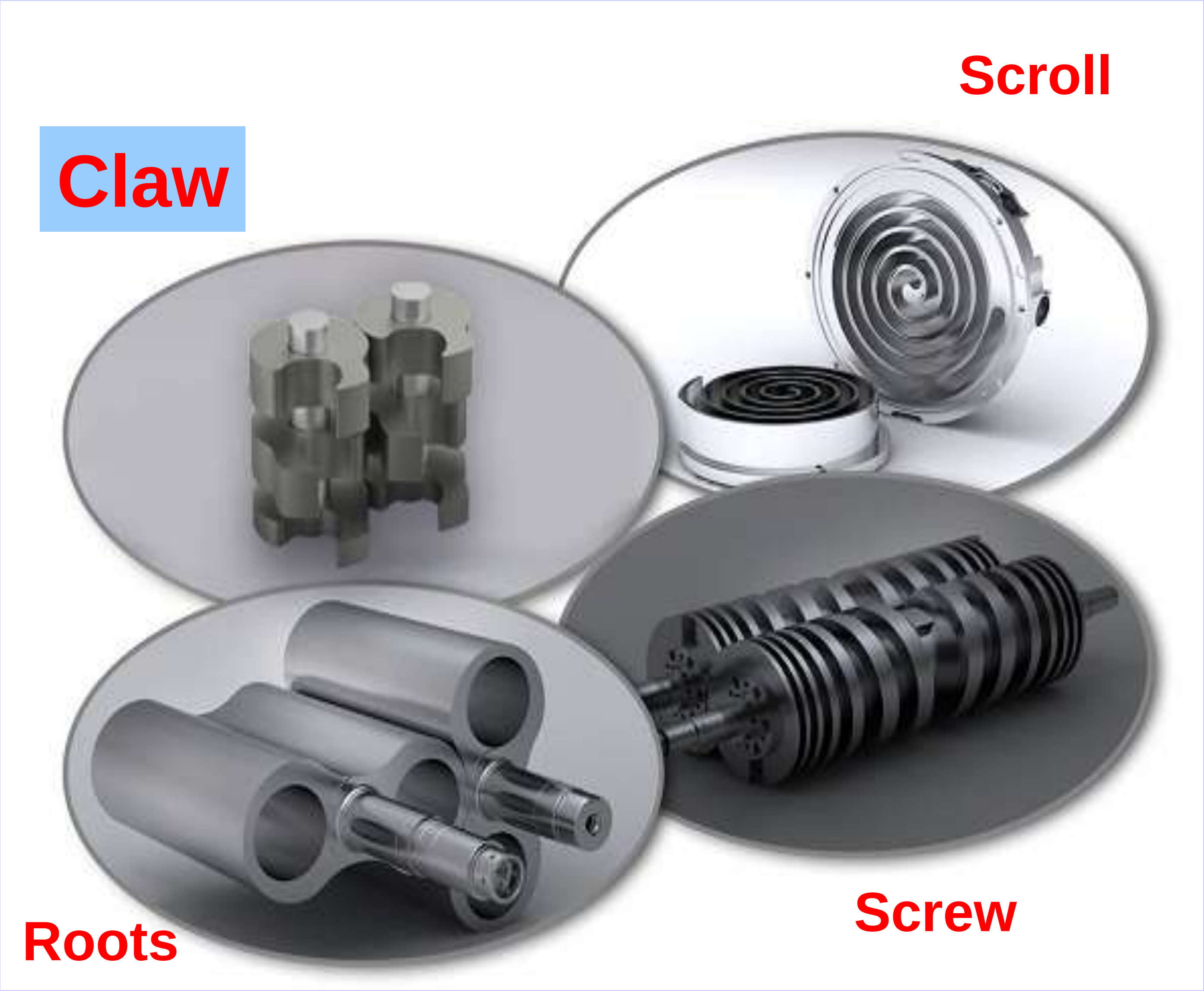
Scroll Pump

- Small exhaust stage
  - Low power at ultimate
- Progressive compression
  - No sudden opening and closing of trapped volumes until final exhaust port
- Concentric arrangement of “stages”
  - Compact mechanism
- Few & simple external seals
- Can be made completely dry with no dynamic seals between lubricant and pump volume
- Reasonable light gas pumping
  - He speed ~ 50% to 70% air speed
  - H_2 , mixed with N_2 for safety reasons

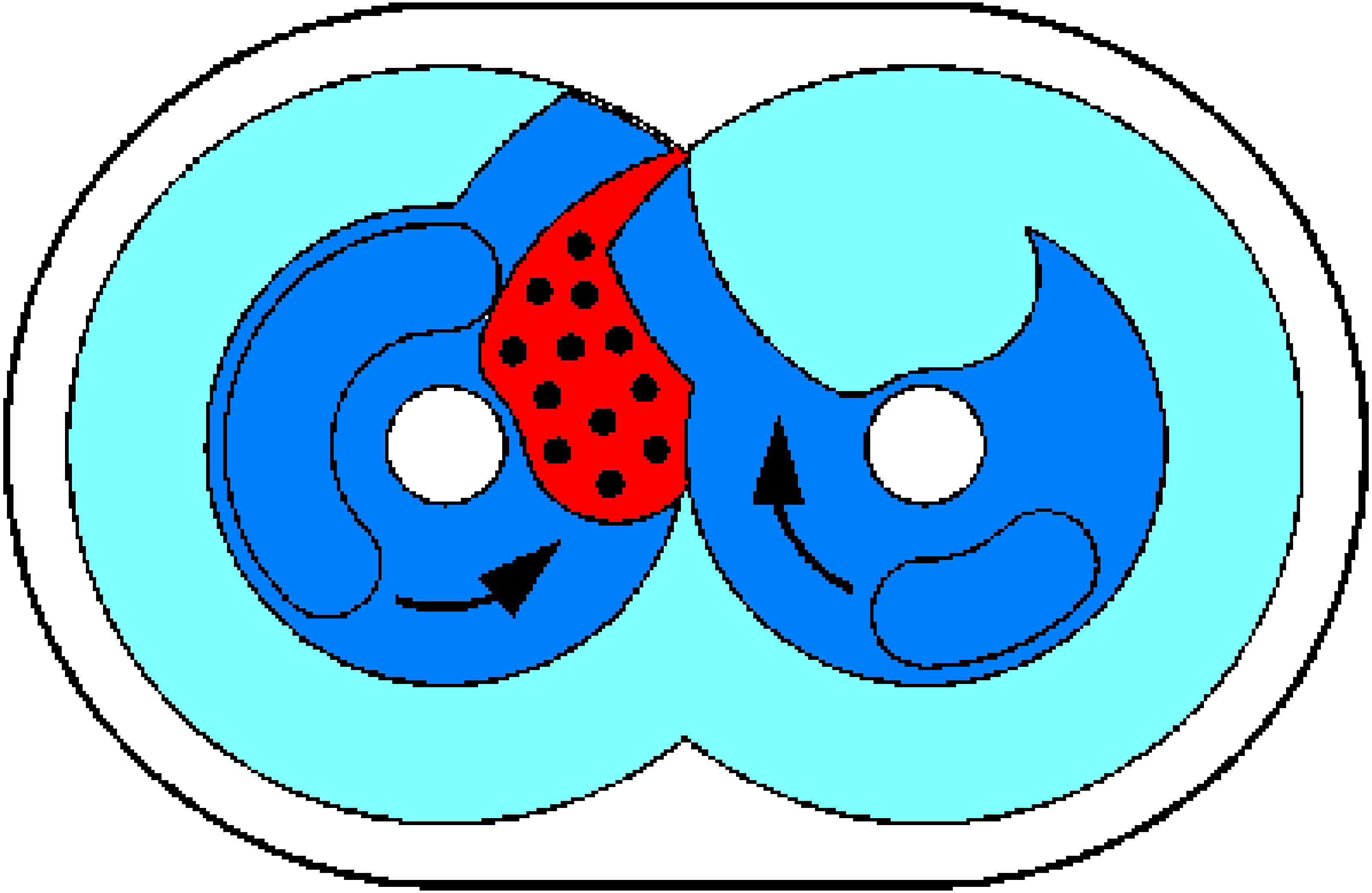
Scroll Pump

- Difficult to extract heat from the exhaust stages
  - Small size, located on axis
- Seal wear generates dust
  - Mainly in first 100 hours, not a major problem if no suckback
  - Successfully used in electron microscopes which are very sensitive to dust
- Seals require frequent maintenance
- Highly vulnerable to solid material ingestion
- Clearances controlled at “whole pump level”
  - Less easy to control critical exhaust clearances
- Only small capacity pumps available – difficult to scale to large sizes

Dry Pump Technologies



Claw Pumps



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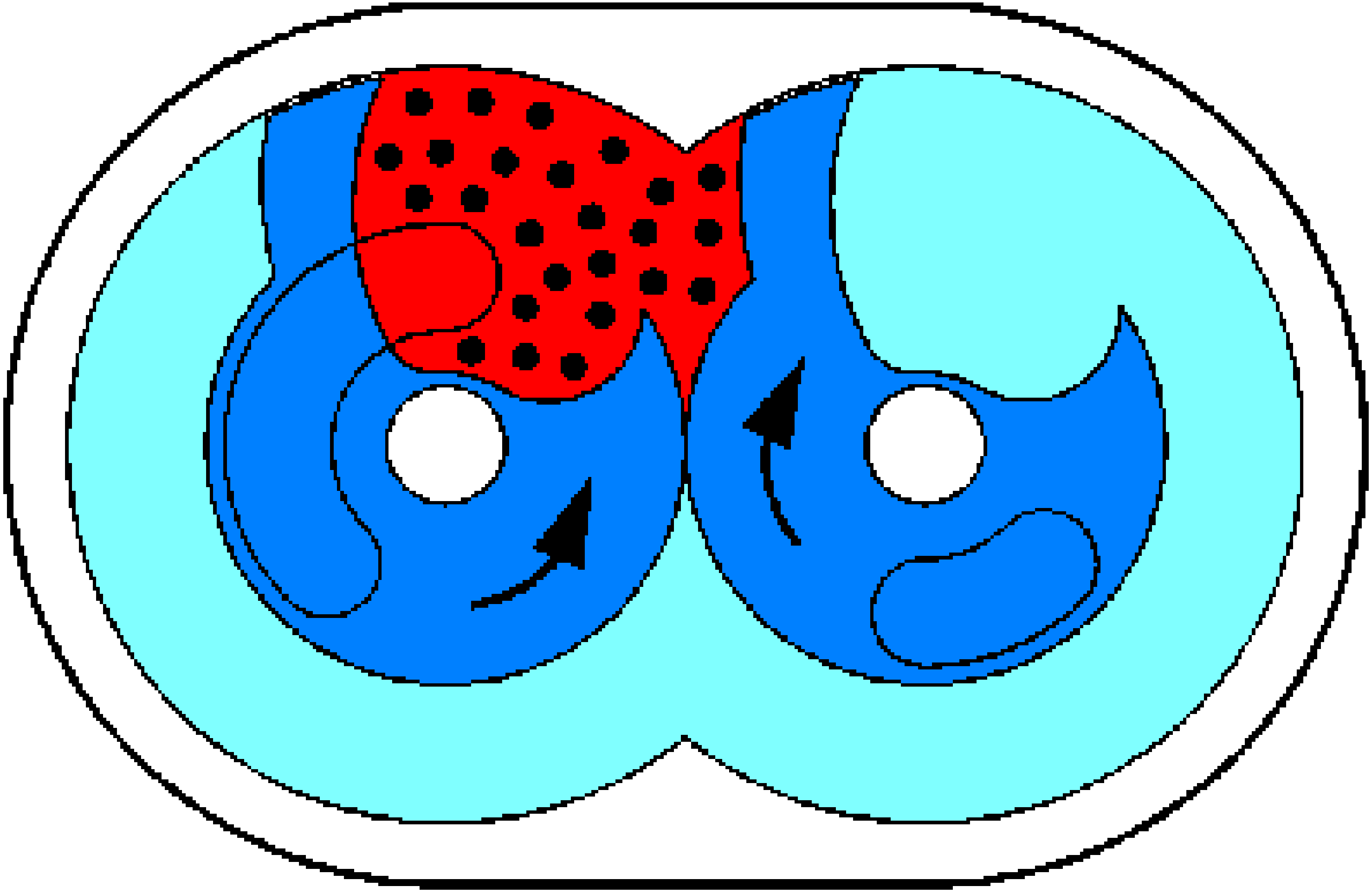

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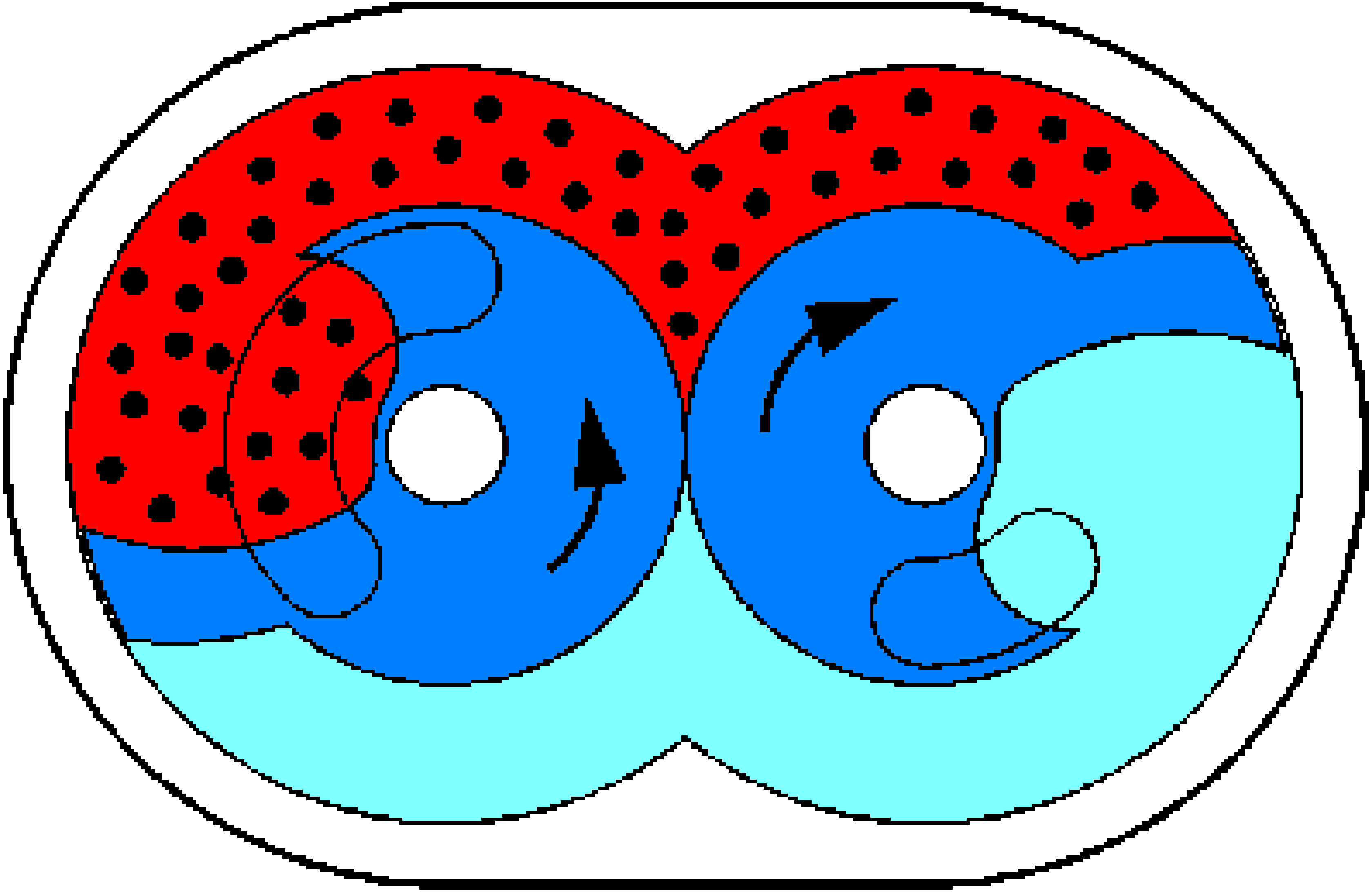

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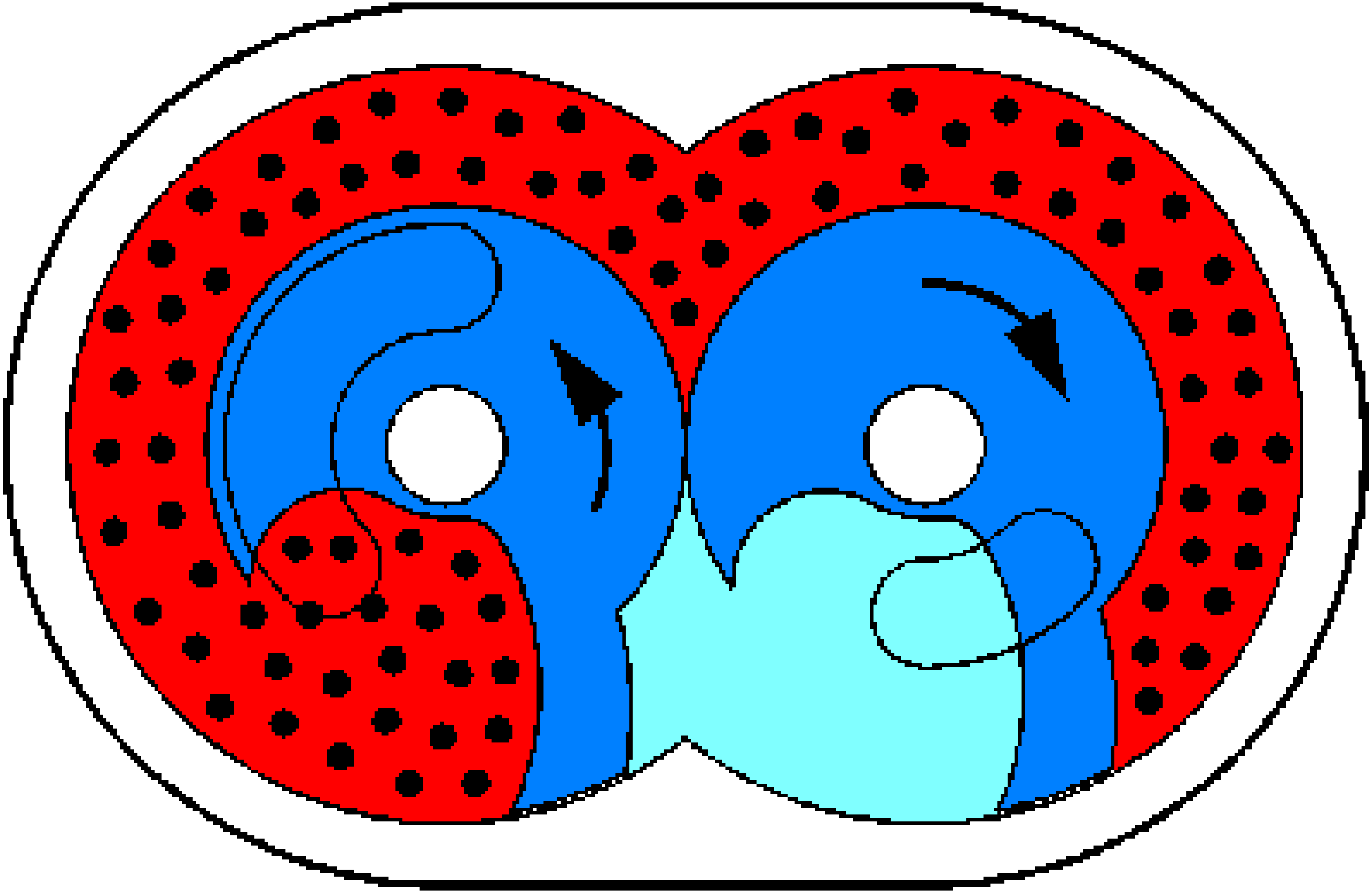

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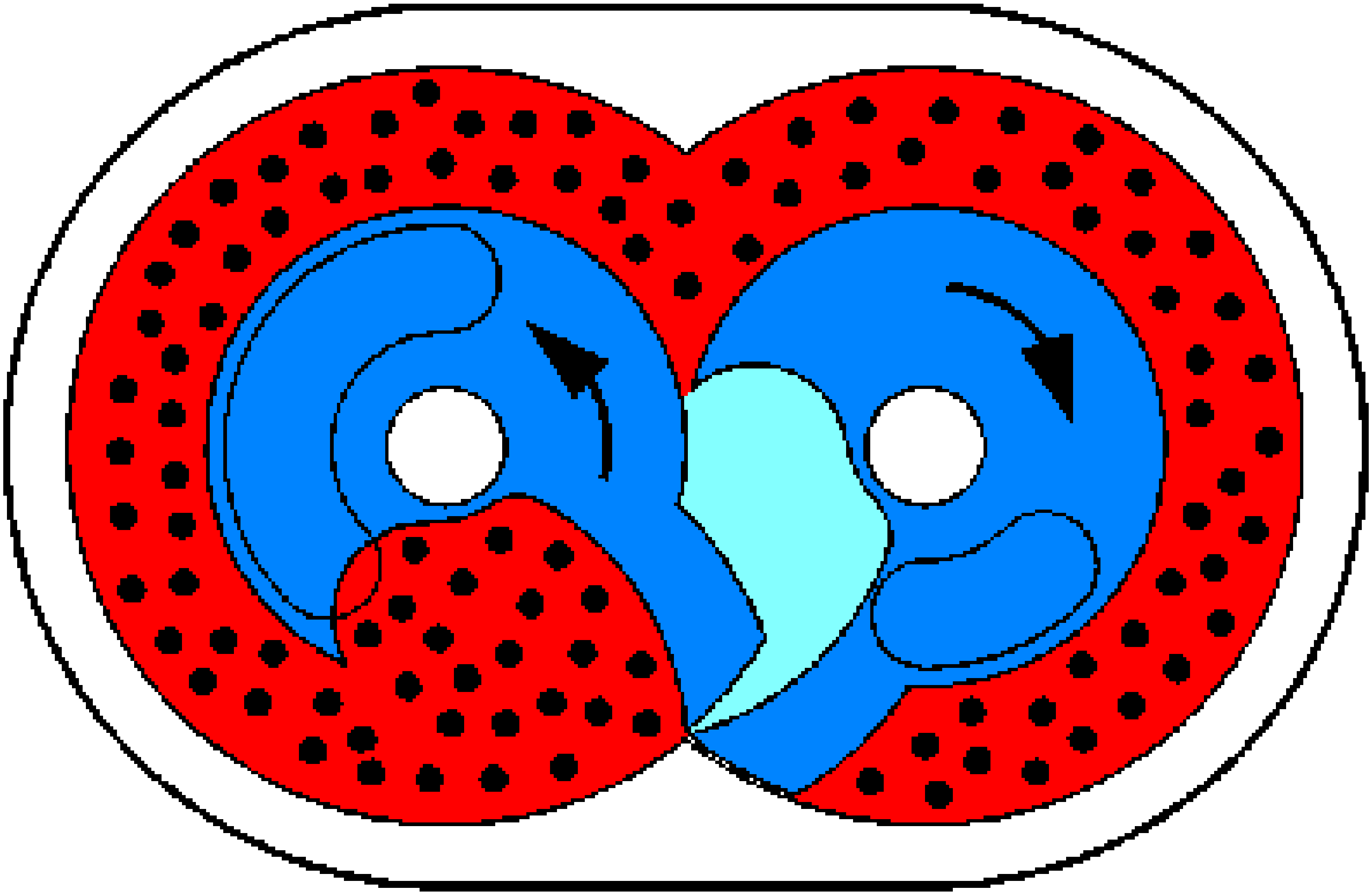

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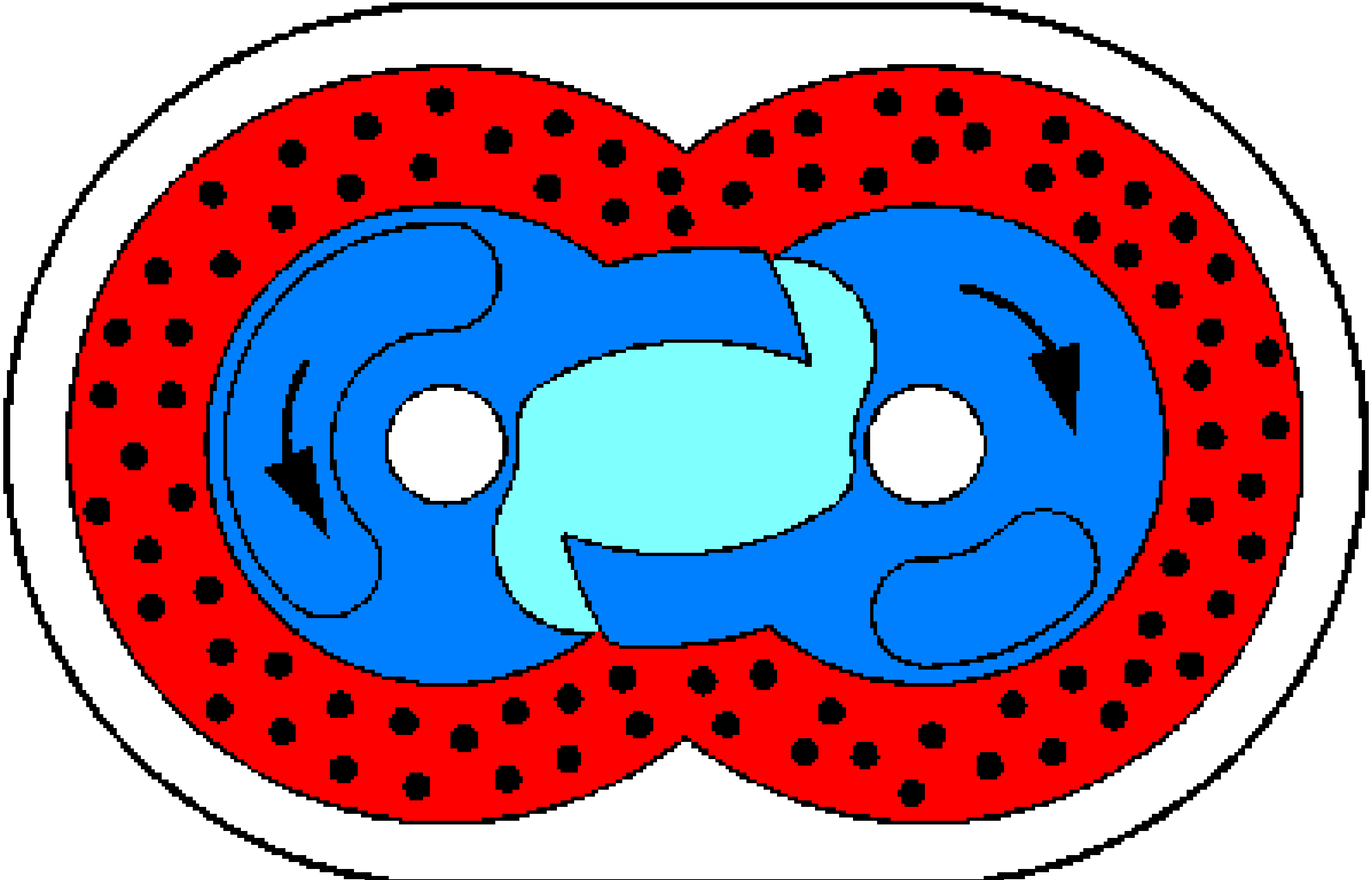

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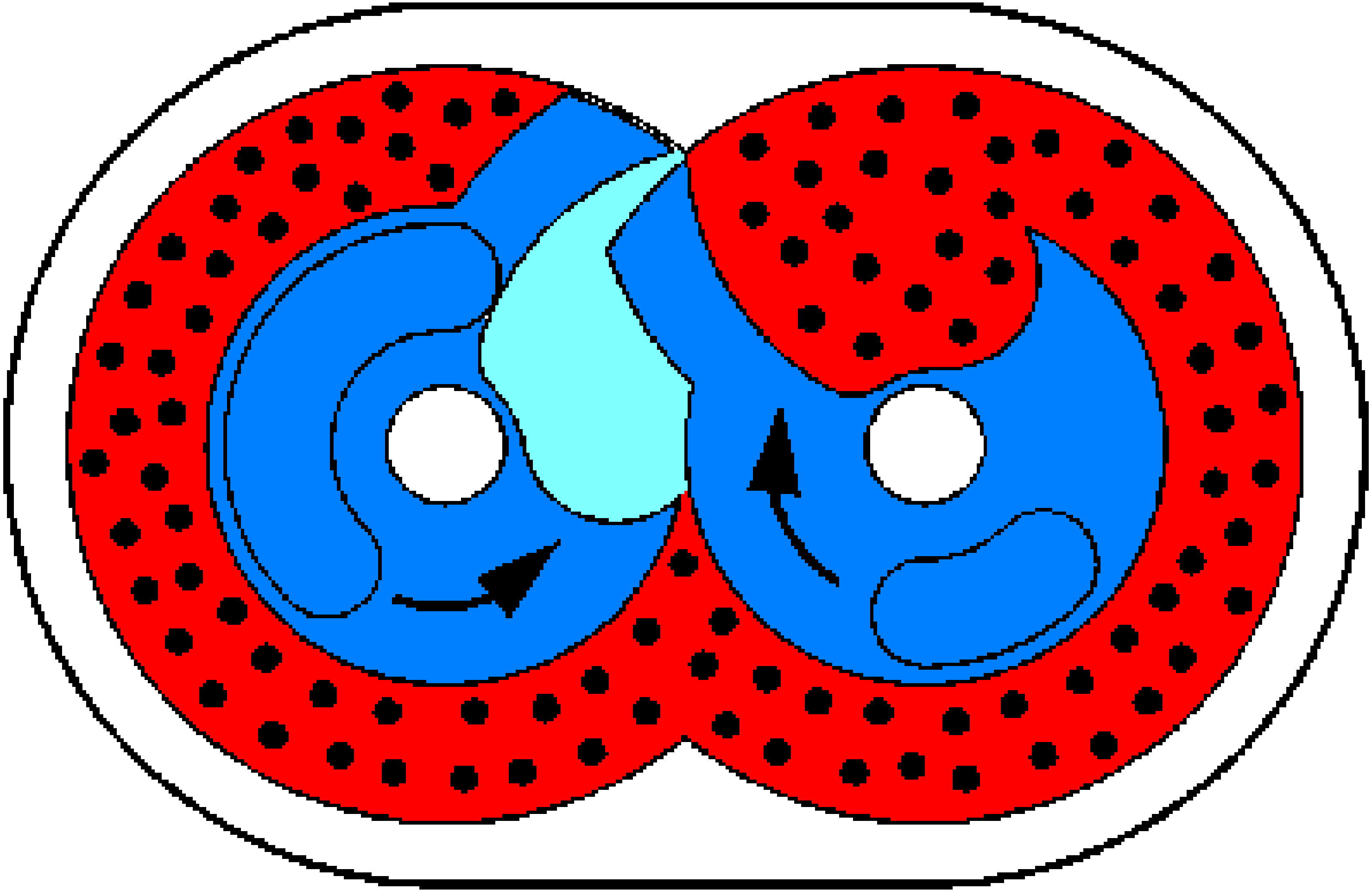

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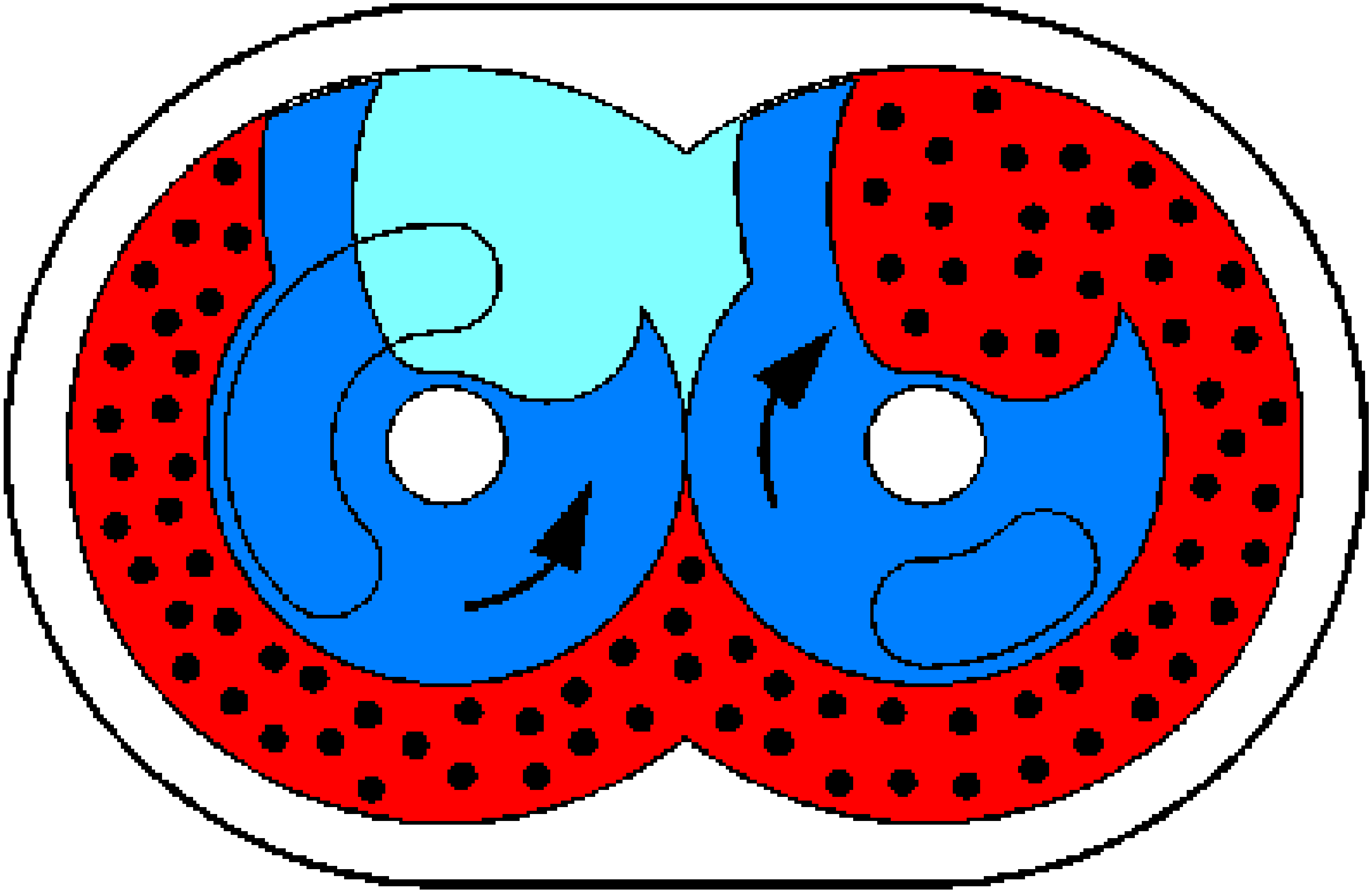

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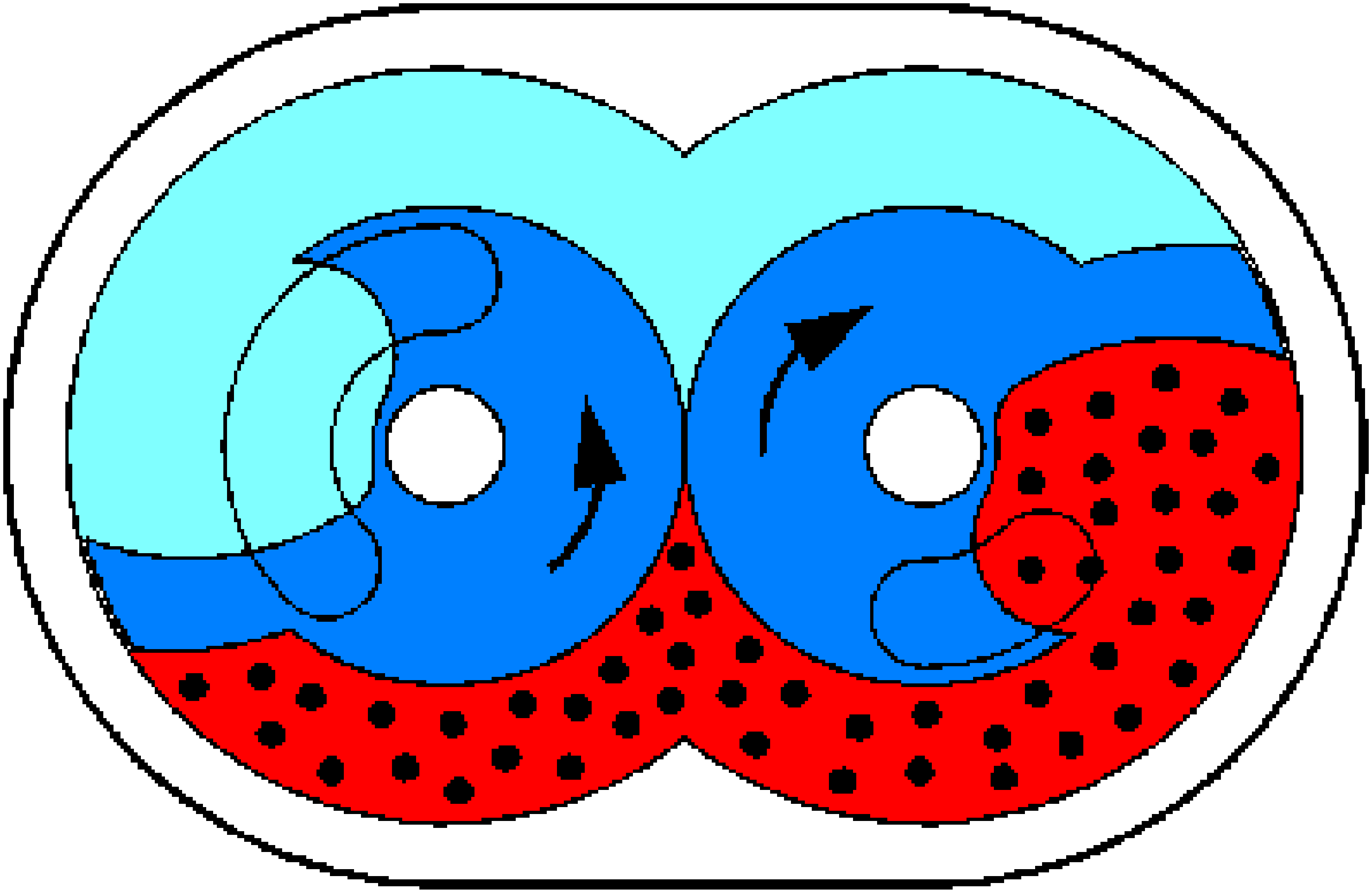

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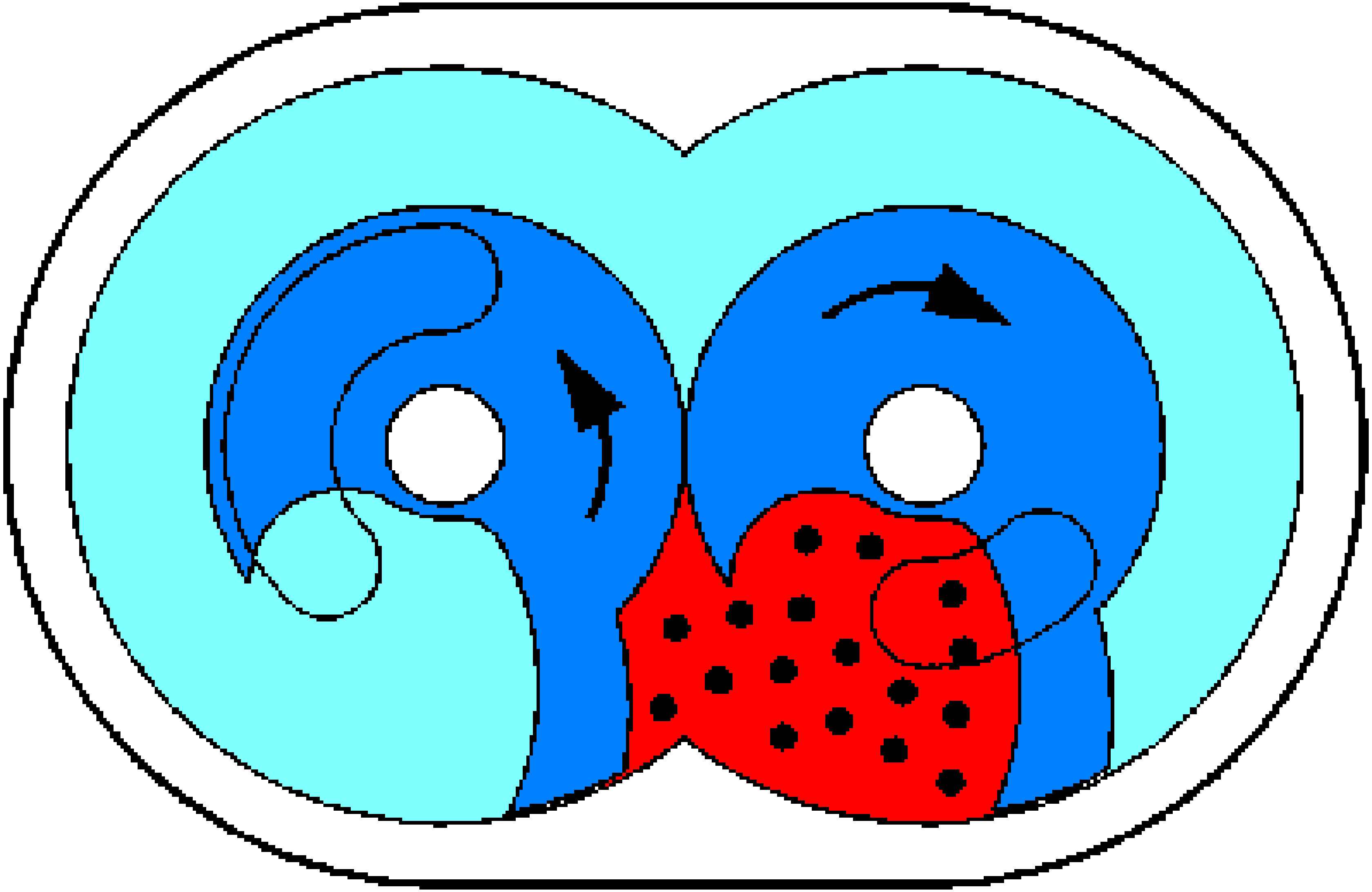

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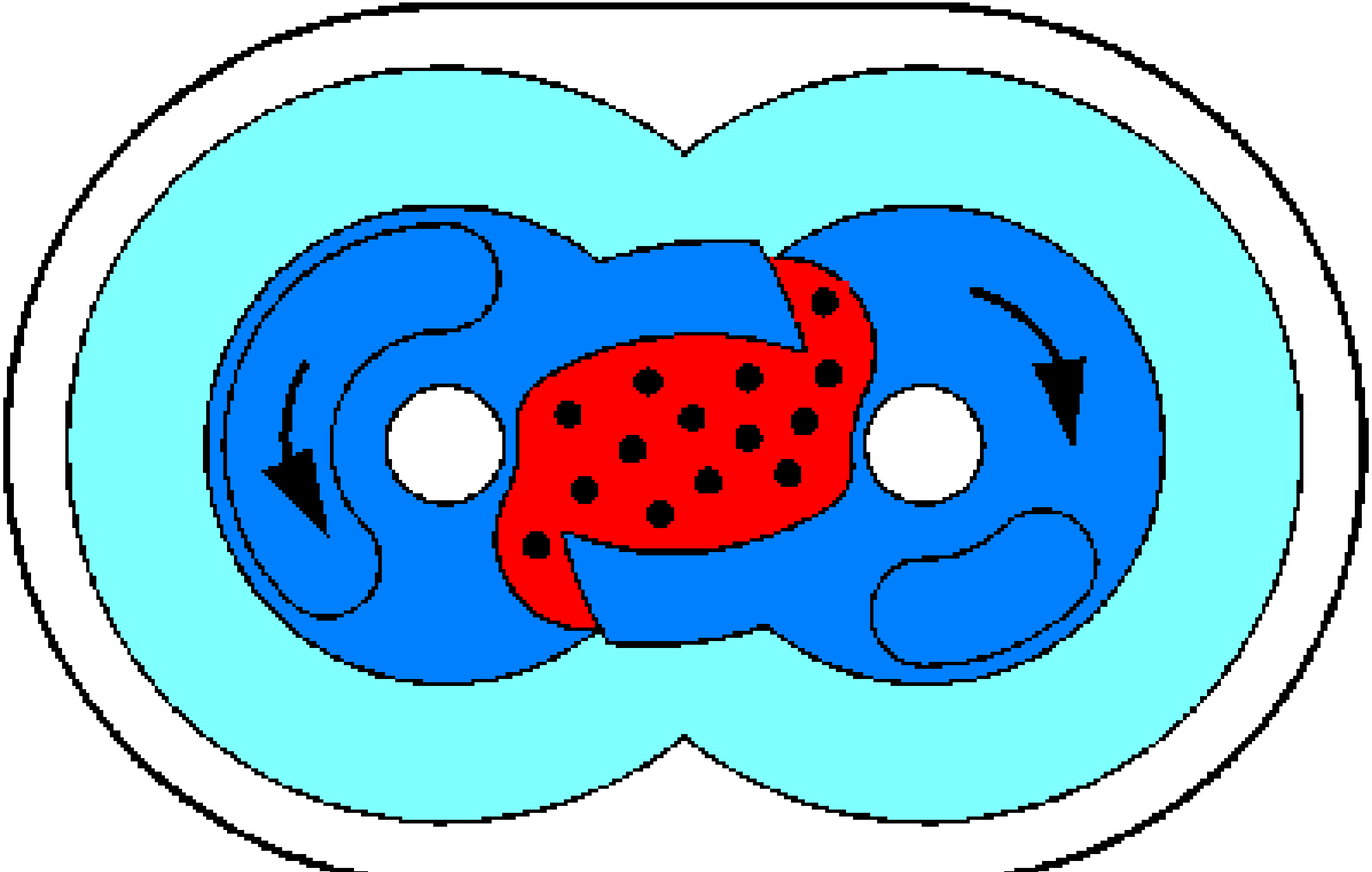
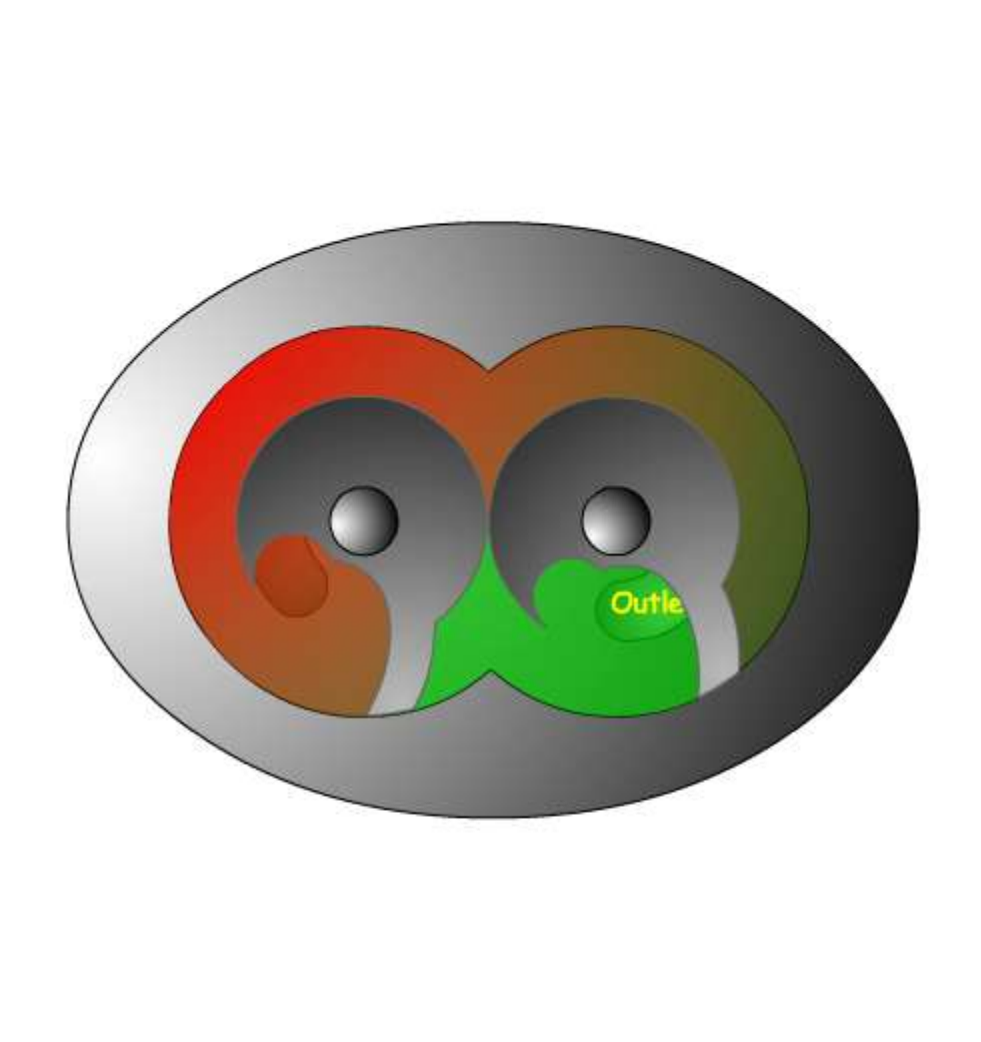


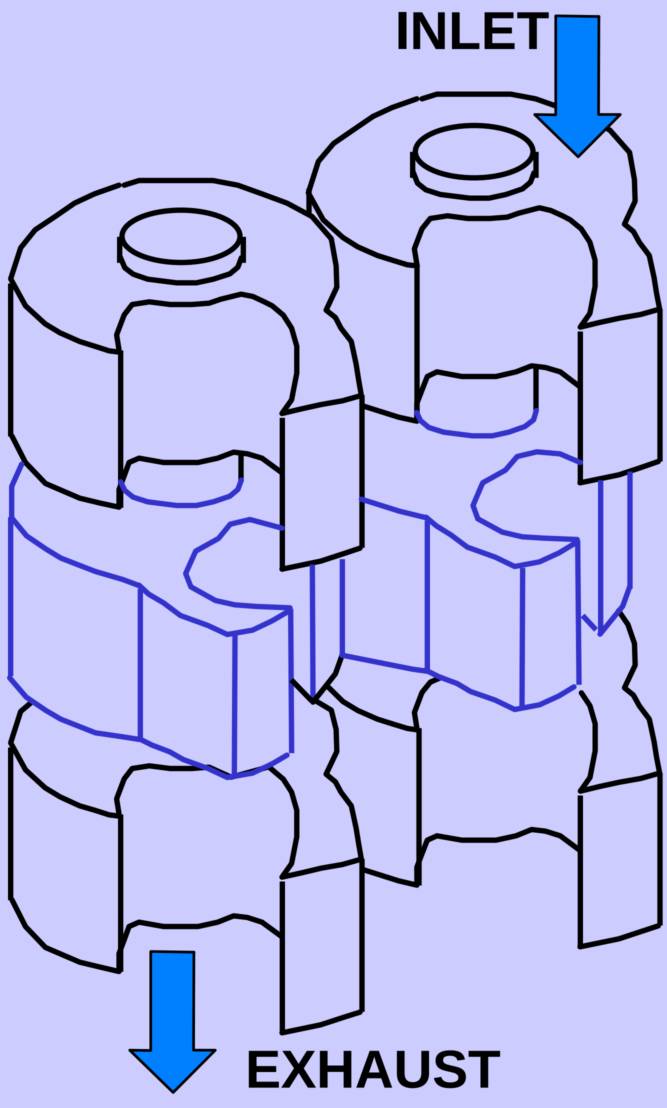
Ideal Compression Ratio

- If V = swept volume and v = dead volume
- It might be thought that the ideal compression ratio CR = V/v
- However, the dead volume re-expands into the pump volume and CR ~ $(V/v)^2$



Claw Pumps

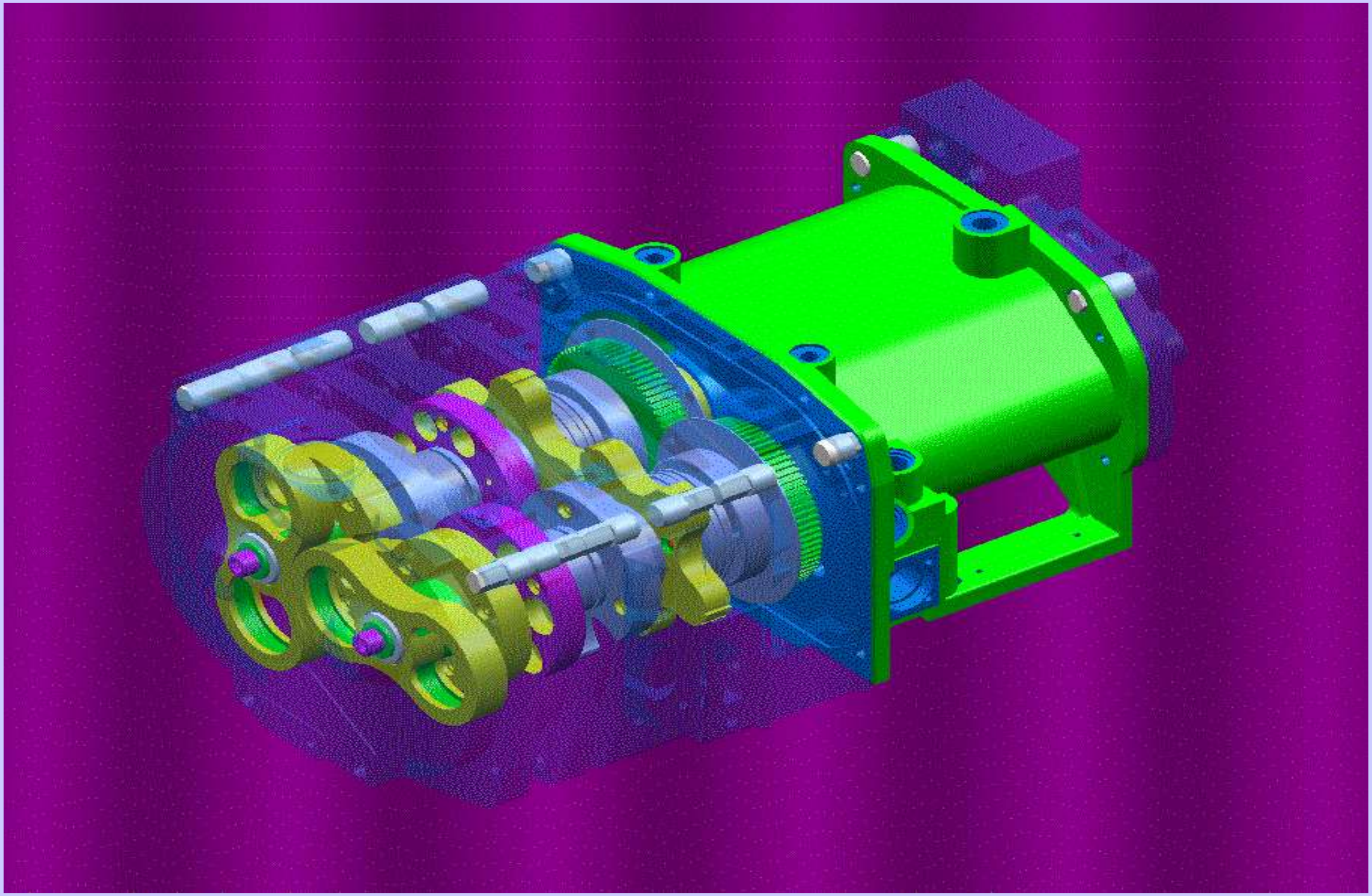
- Good compression
- Compression through pump can be controlled by sizing stages
  - Relatively easy to produce small capacity / low power outlet stages
- Reversed claws allow straight path – good dust handling
- Can handle liquid ingestion
- Can be scaled up to moderately large capacities
- Self valving – can exhaust to high pressure



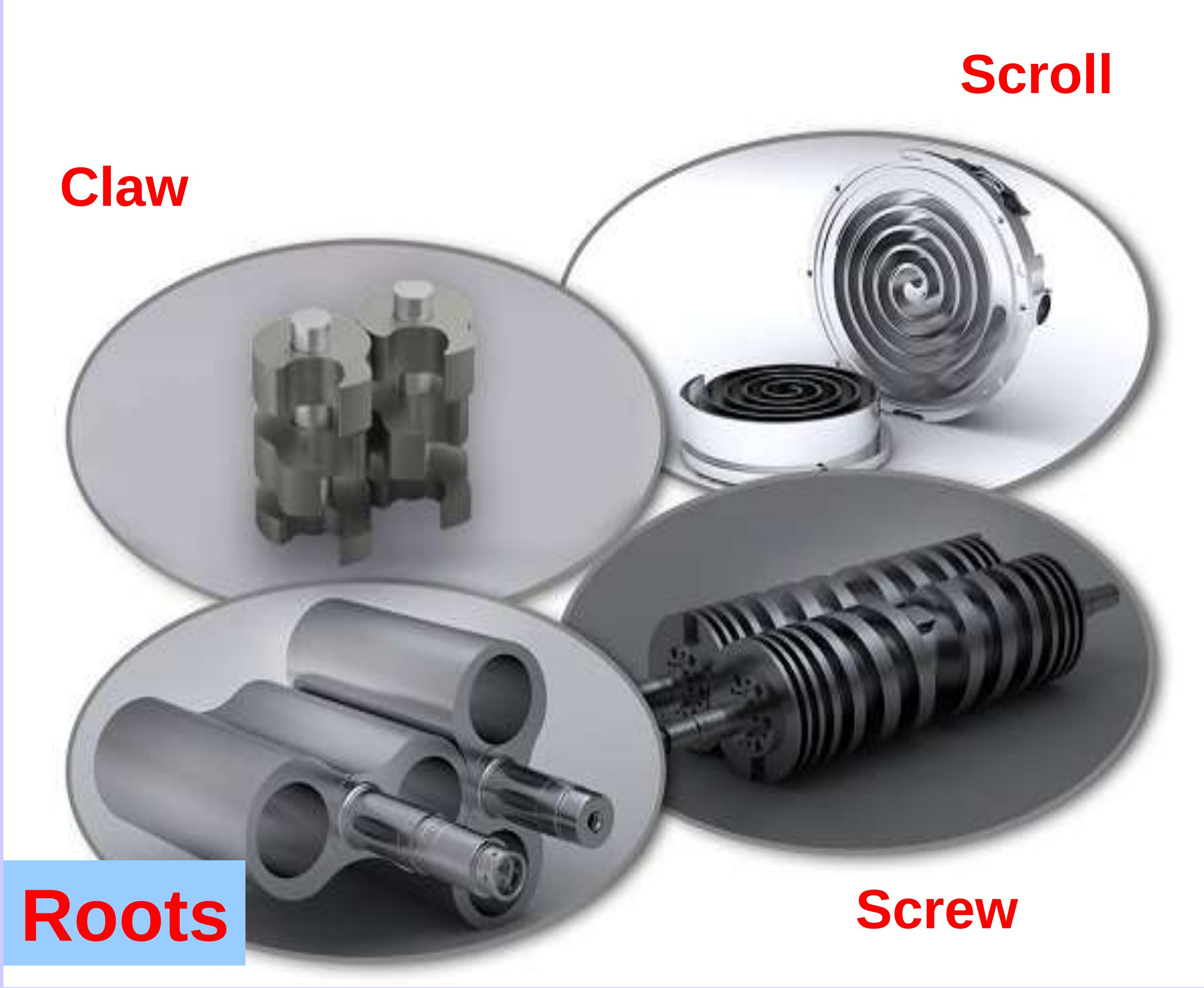
Claw Pumps

- Abrupt compression
  - Exhaust gas re-expands into mechanism at each stage
- Tolerance build up across stages increases clearance at one end of pump (usually inlet)
- Single pulse per rotation at discharge of claw stage
  - High noise when used as an exhaust stage
- Valves and ports can increase power / reduce flow at high pressure
- Lower capacity than same centres Roots
- Relatively poor light gas performance

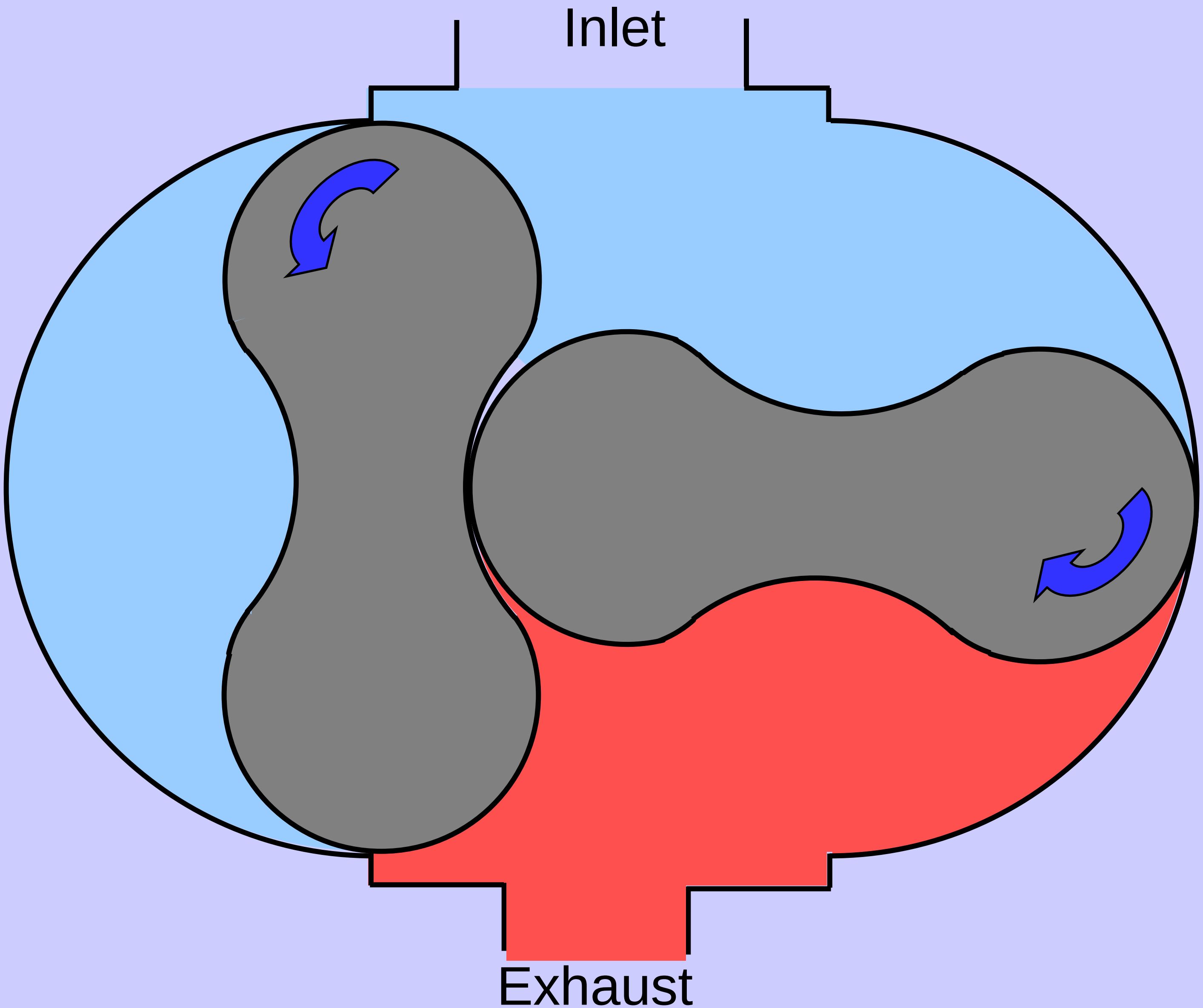
Roots/Claw combination



Dry Pump Technologies



Roots Pumping Cycle



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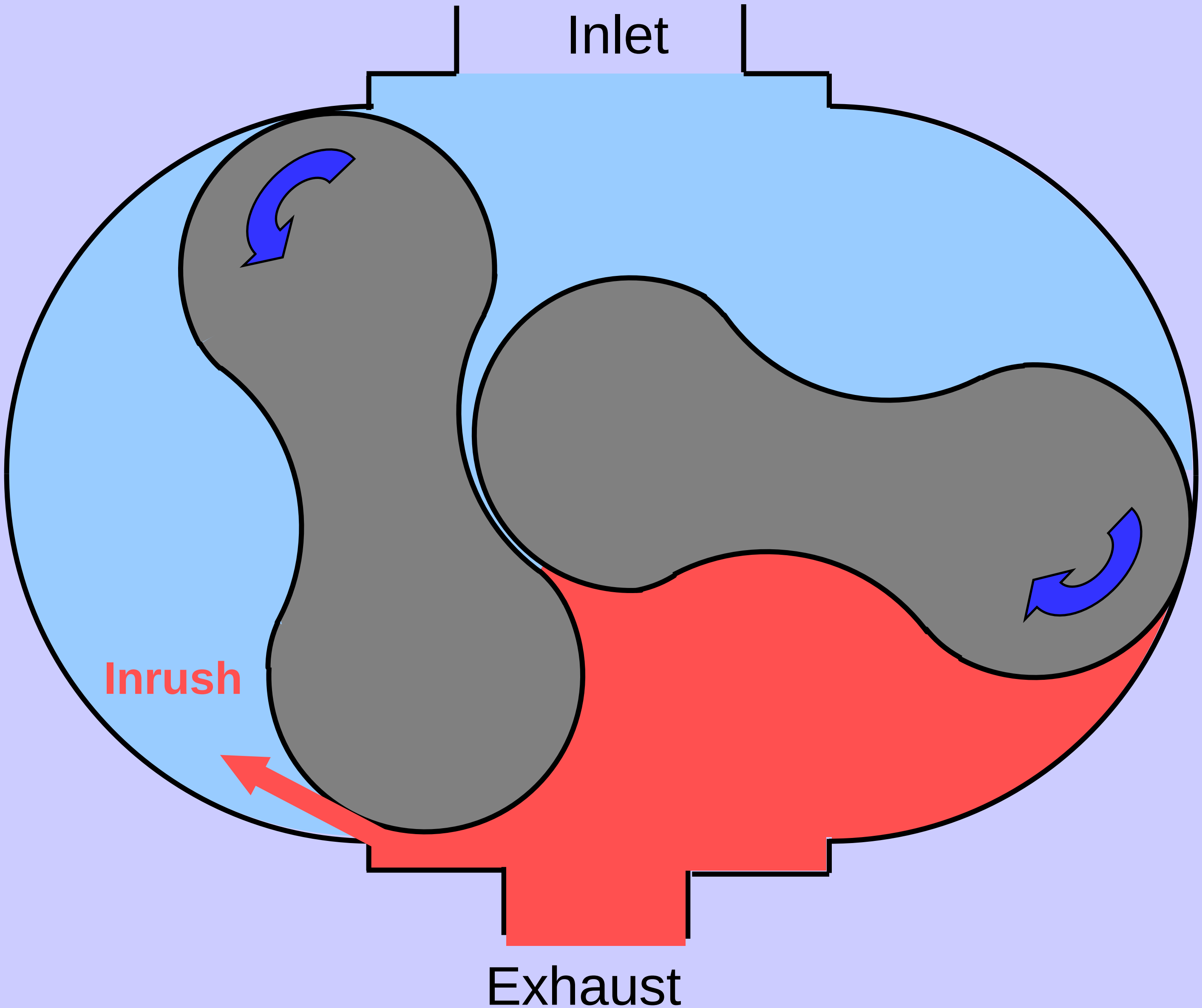

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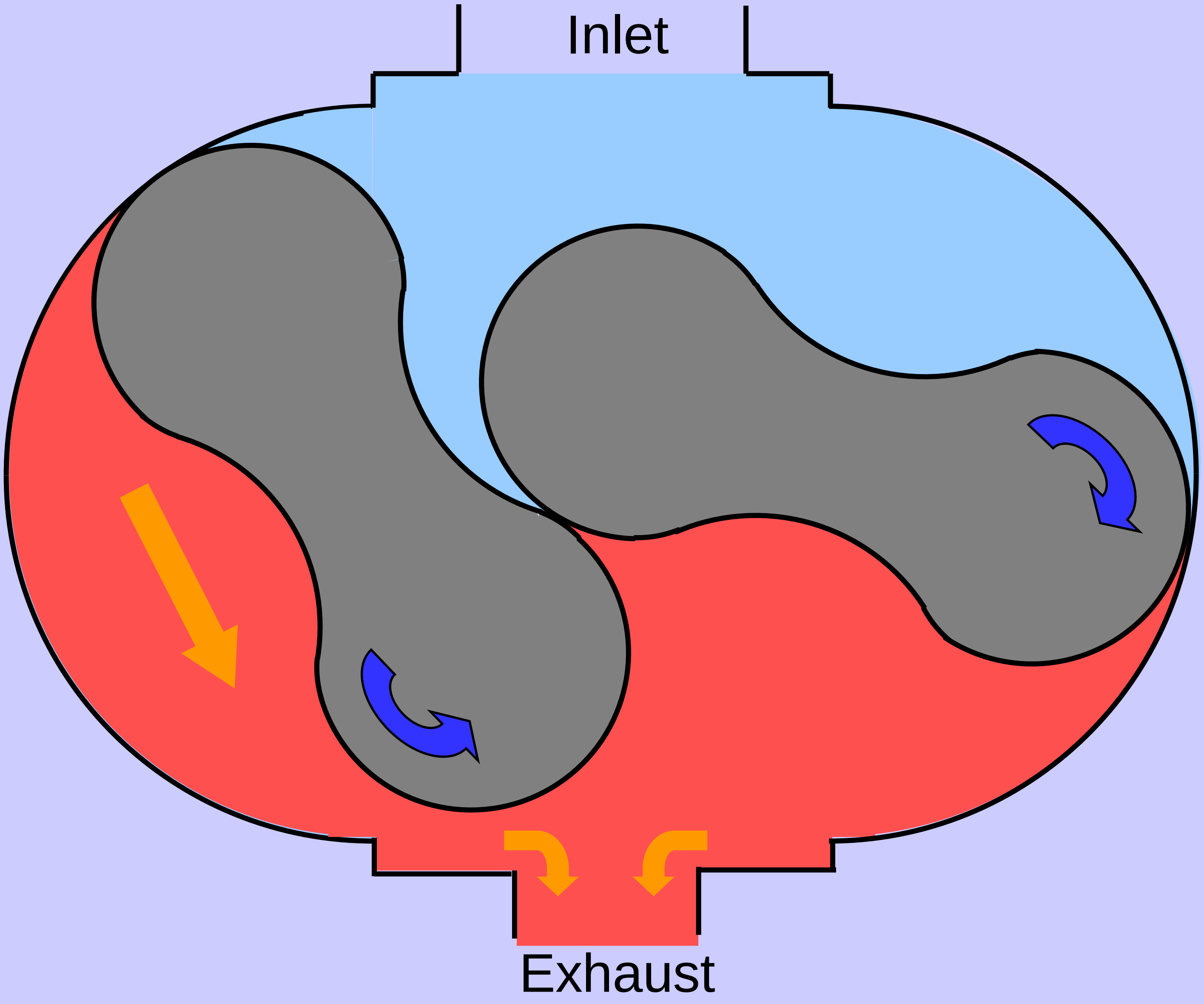

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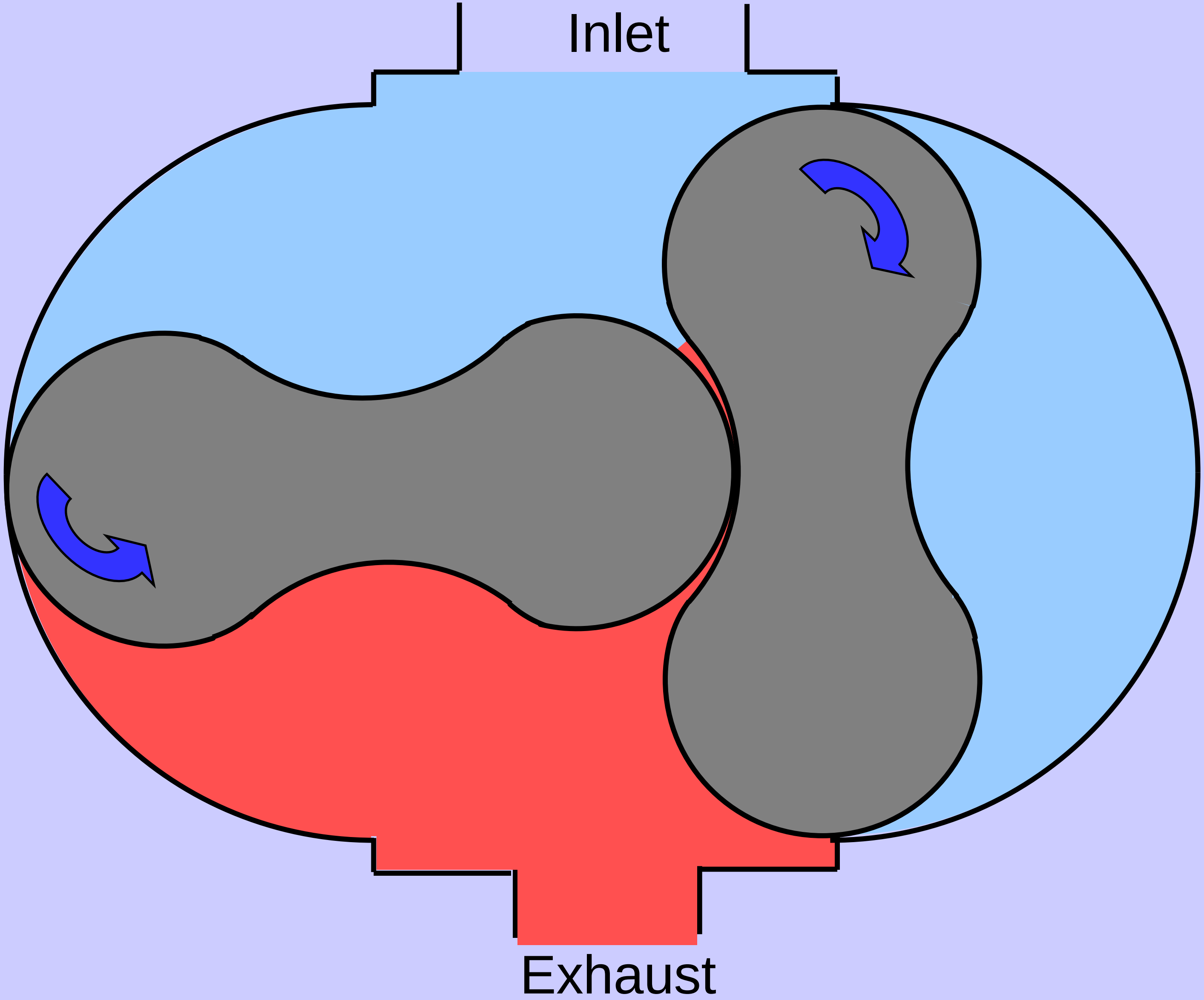

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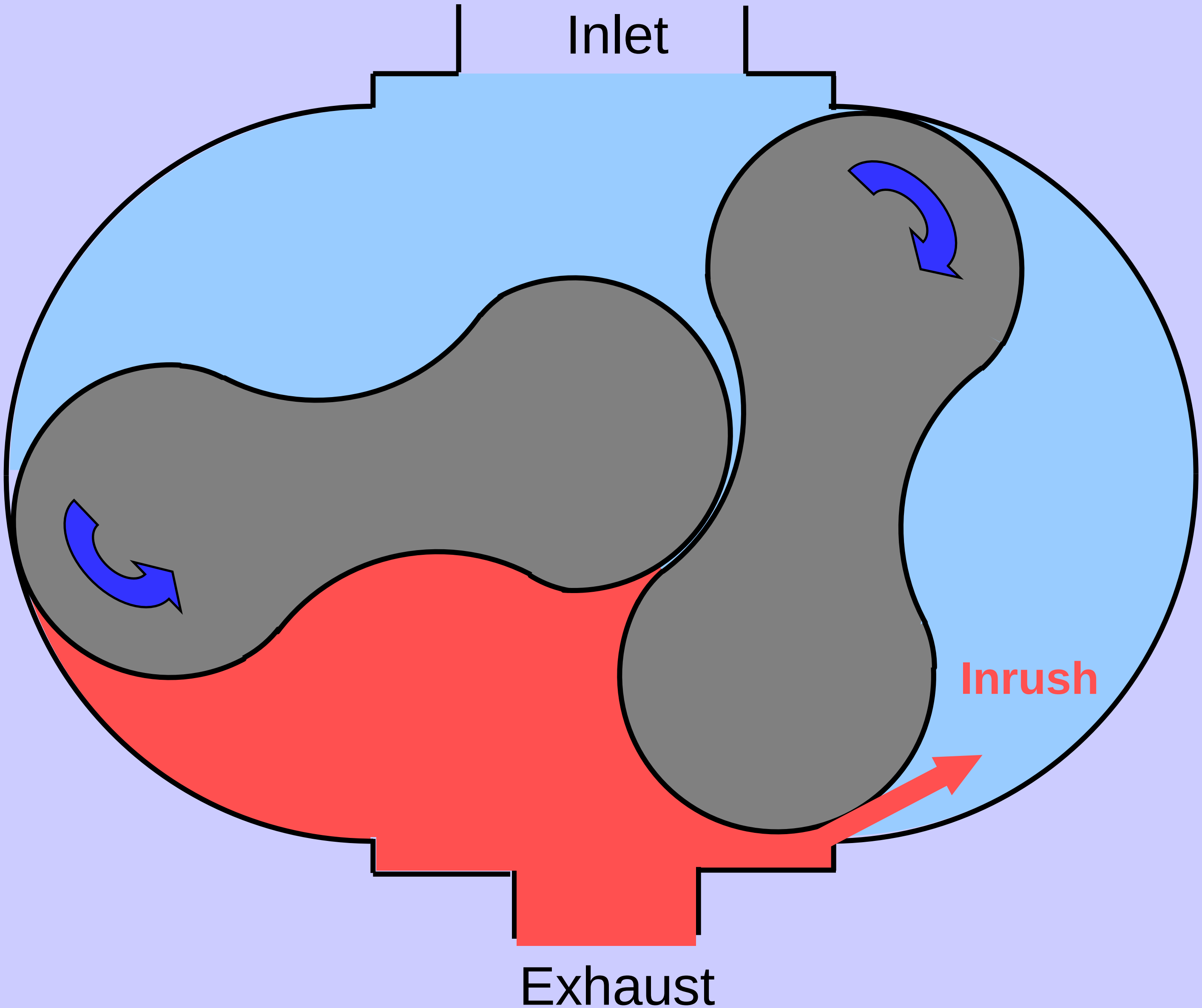
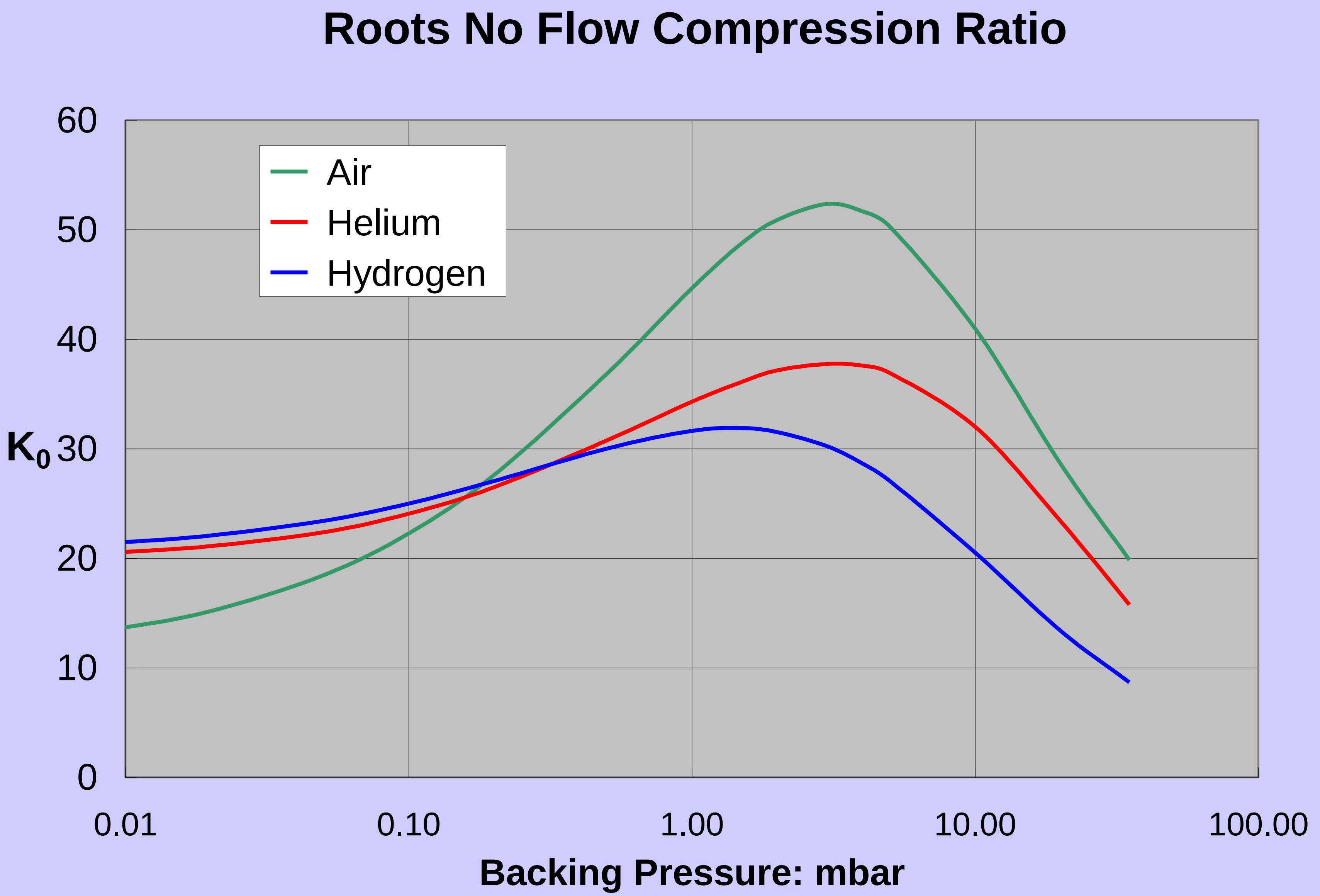
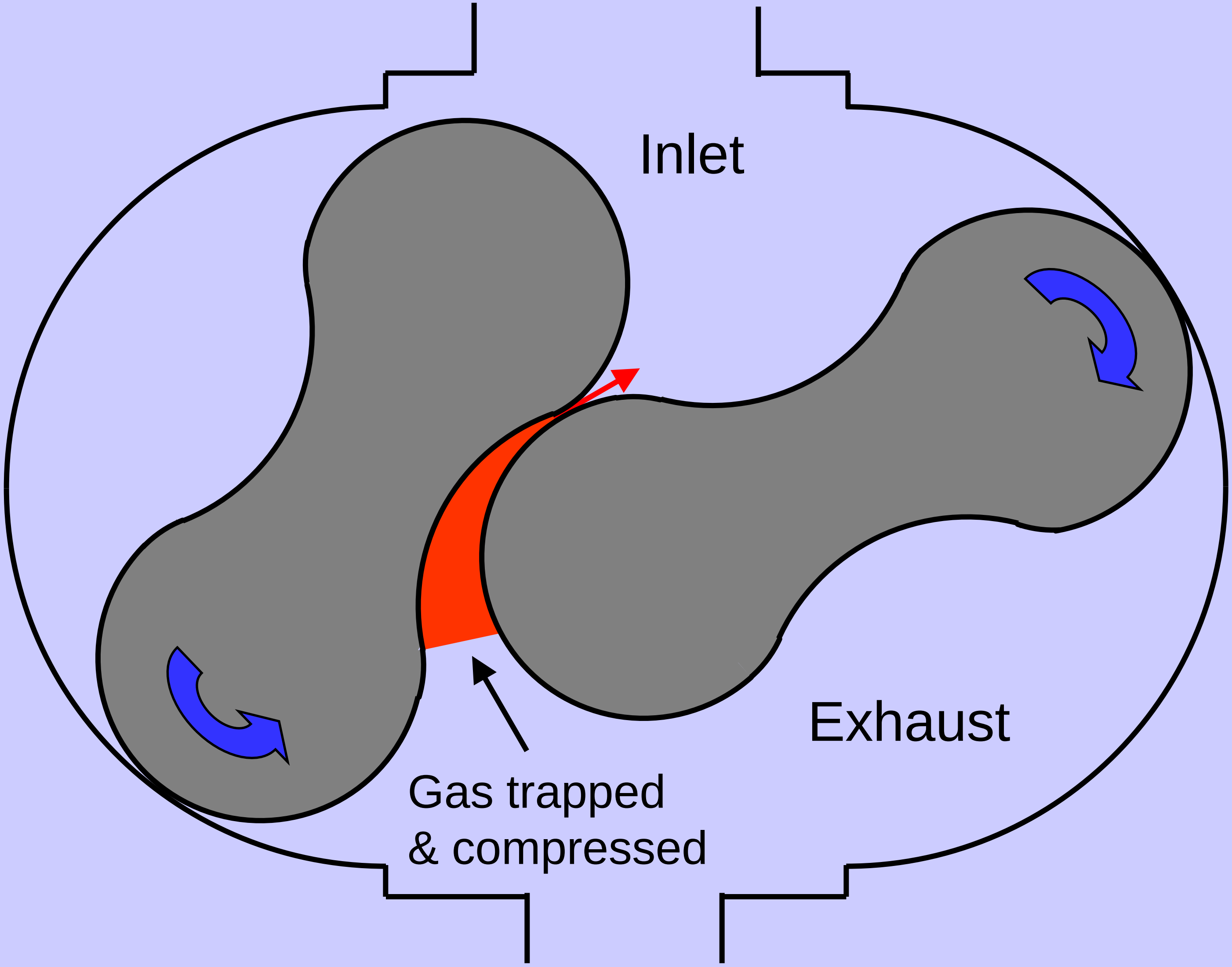


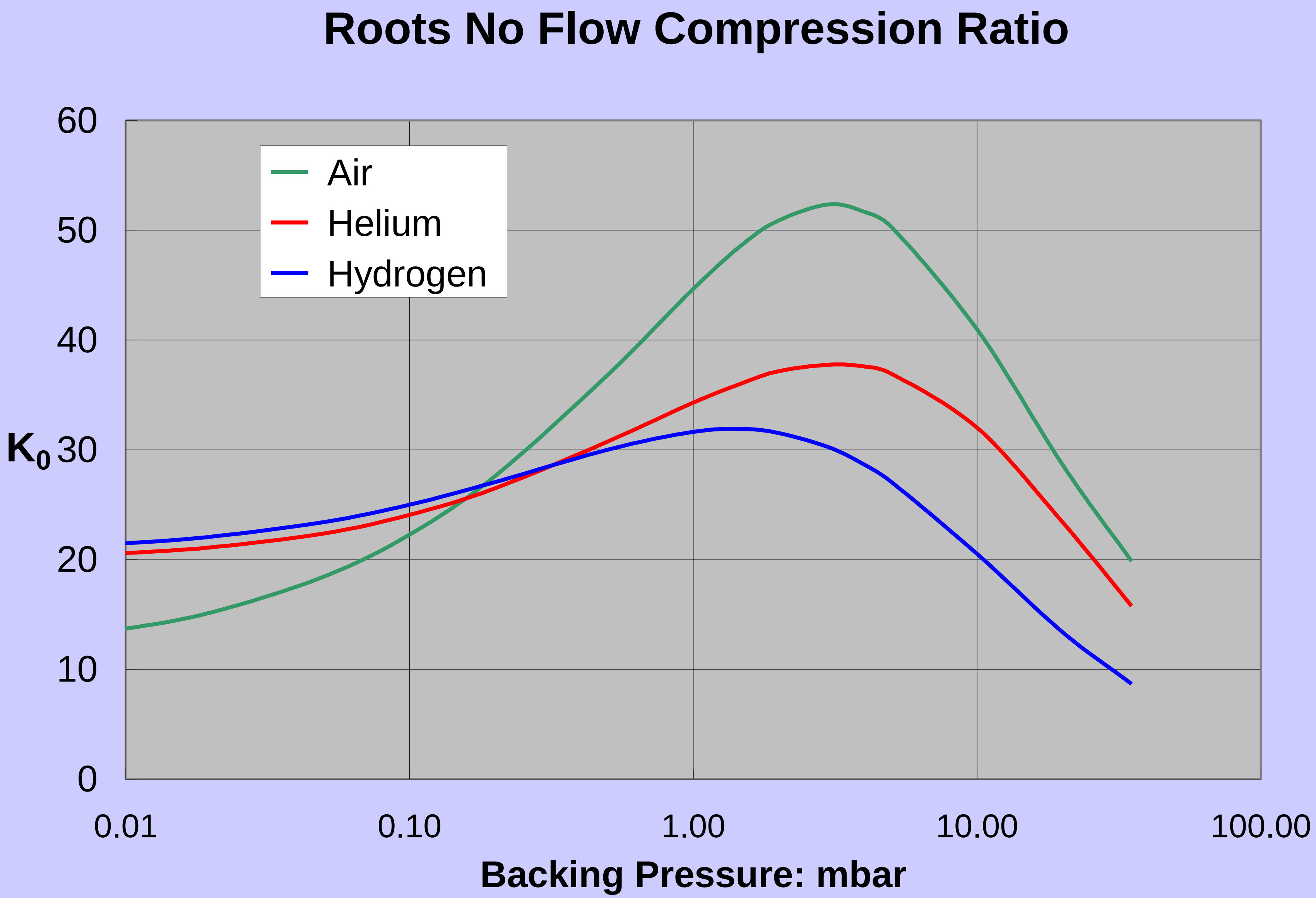
Roots performance



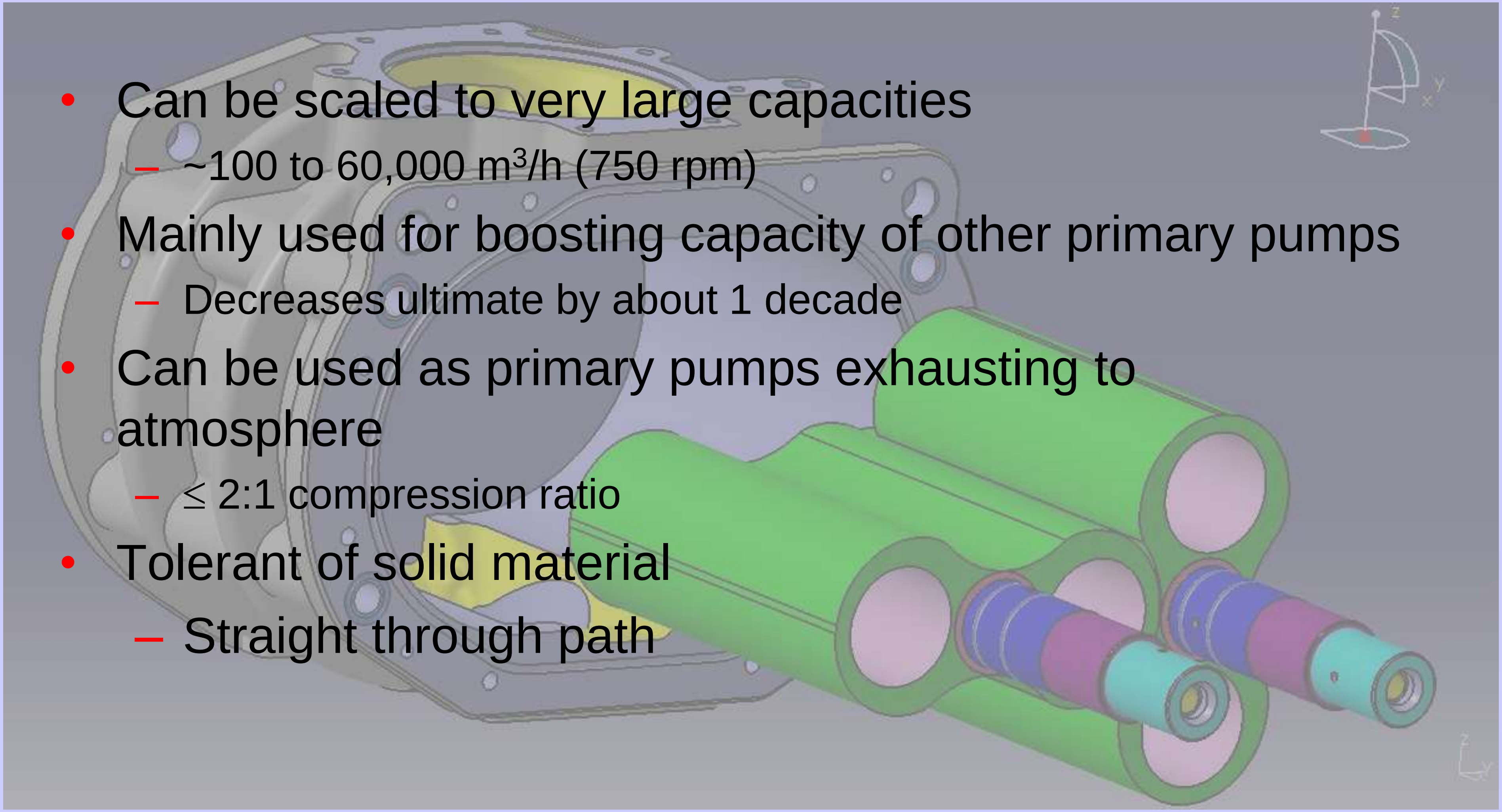
Root Trapping



Effect of root trapping

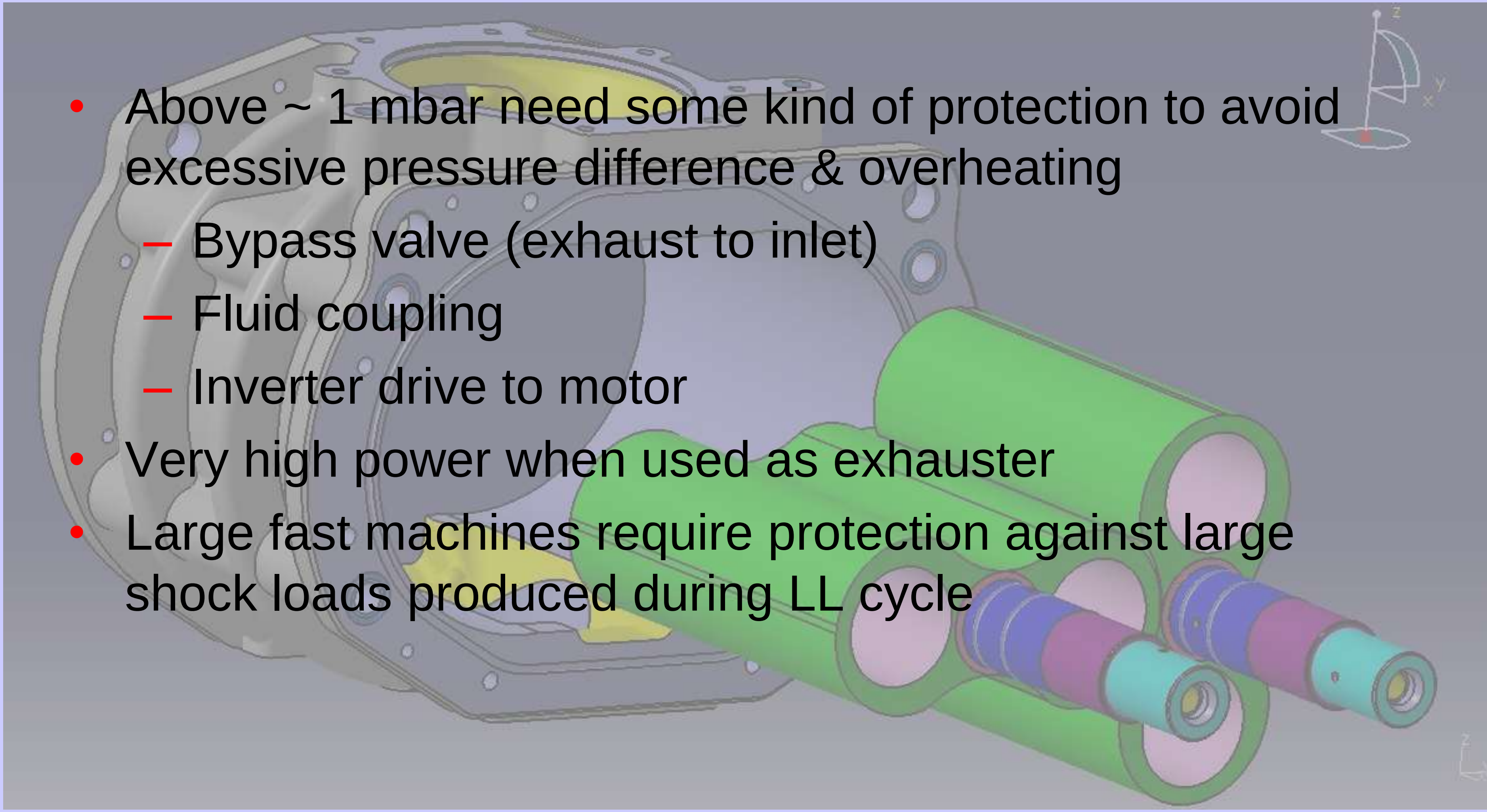


Single Stage Rootes



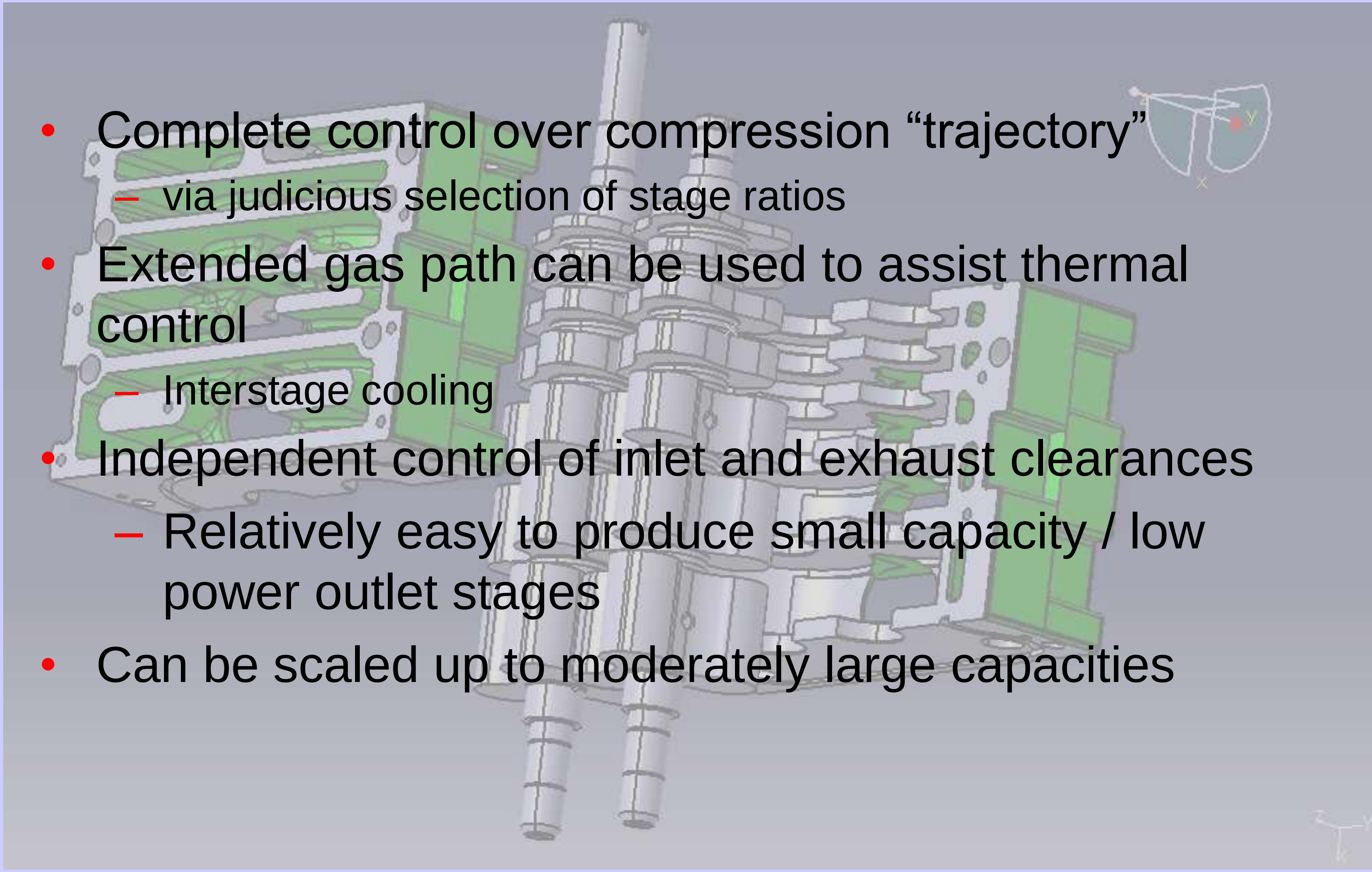
- Can be scaled to very large capacities
  - ~100 to 60,000 m^3/h (750 rpm)
- Mainly used for boosting capacity of other primary pumps
  - Decreases ultimate by about 1 decade
- Can be used as primary pumps exhausting to atmosphere
  - ≤ 2:1 compression ratio
- Tolerant of solid material
  - Straight through path

Single Stage Rootes



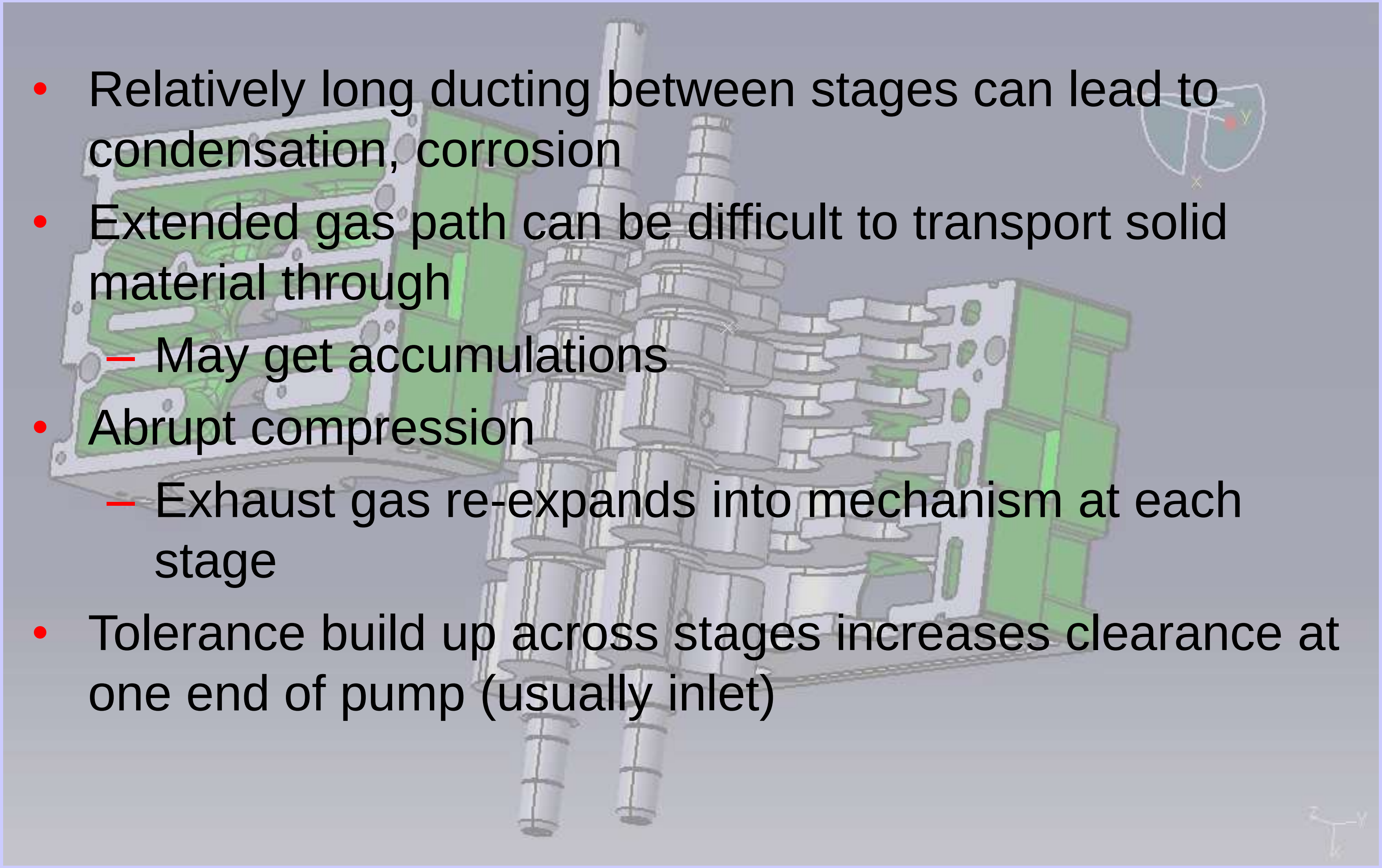
- Above ~ 1 mbar need some kind of protection to avoid excessive pressure difference & overheating
  - Bypass valve (exhaust to inlet)
  - Fluid coupling
  - Inverter drive to motor
- Very high power when used as exhauster
- Large fast machines require protection against large shock loads produced during LL cycle

Multi-Stage Rootes



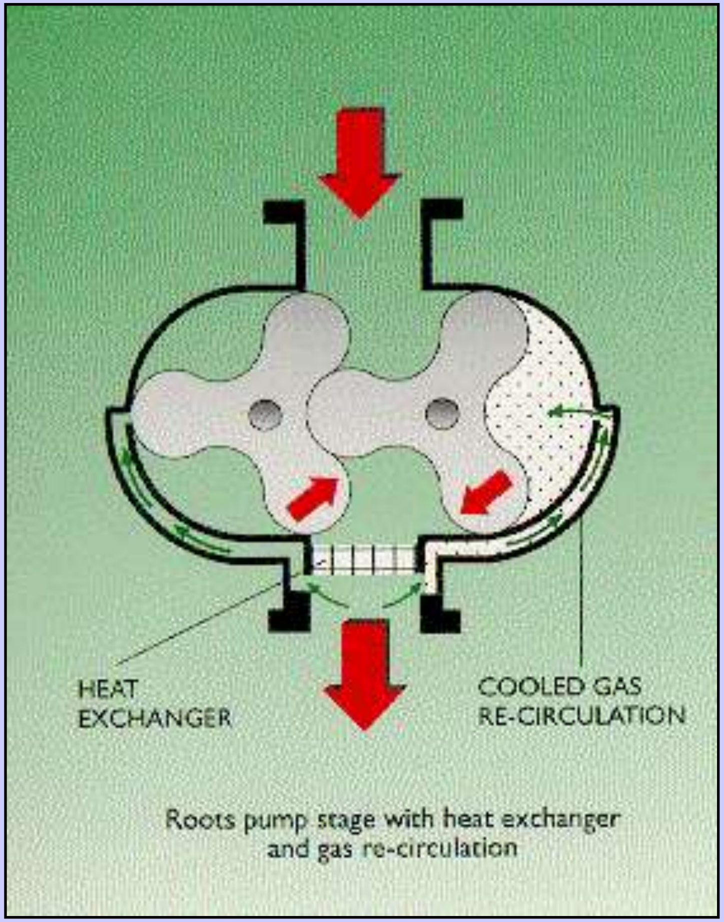
- Complete control over compression “trajectory”
  - via judicious selection of stage ratios
- Extended gas path can be used to assist thermal control
  - Interstage cooling
- Independent control of inlet and exhaust clearances
  - Relatively easy to produce small capacity / low power outlet stages
- Can be scaled up to moderately large capacities

Multi-Stage Rootes



- Relatively long ducting between stages can lead to condensation, corrosion
- Extended gas path can be difficult to transport solid material through
  - May get accumulations
- Abrupt compression
  - Exhaust gas re-expands into mechanism at each stage
- Tolerance build up across stages increases clearance at one end of pump (usually inlet)

Exhaust Cooling



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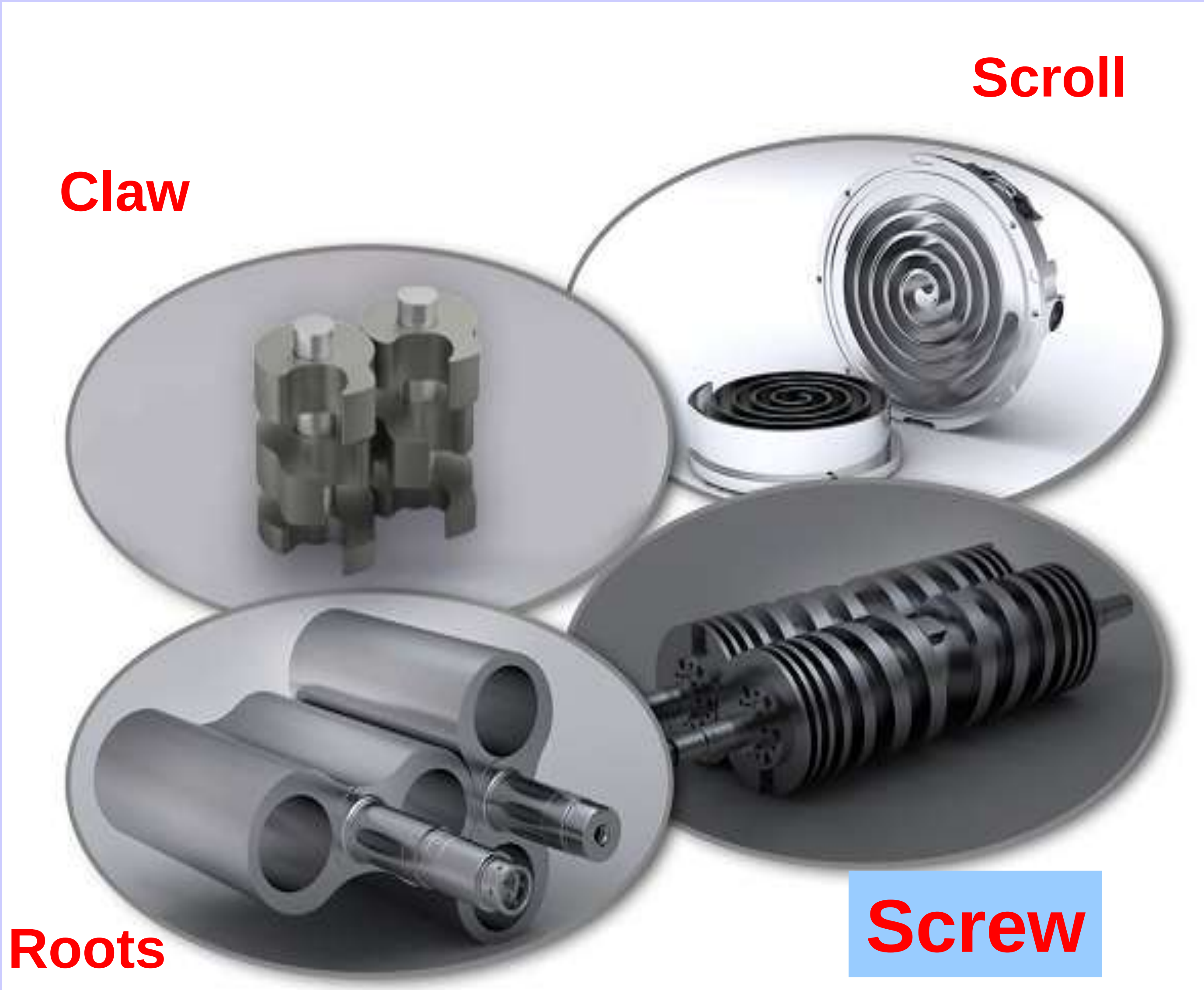
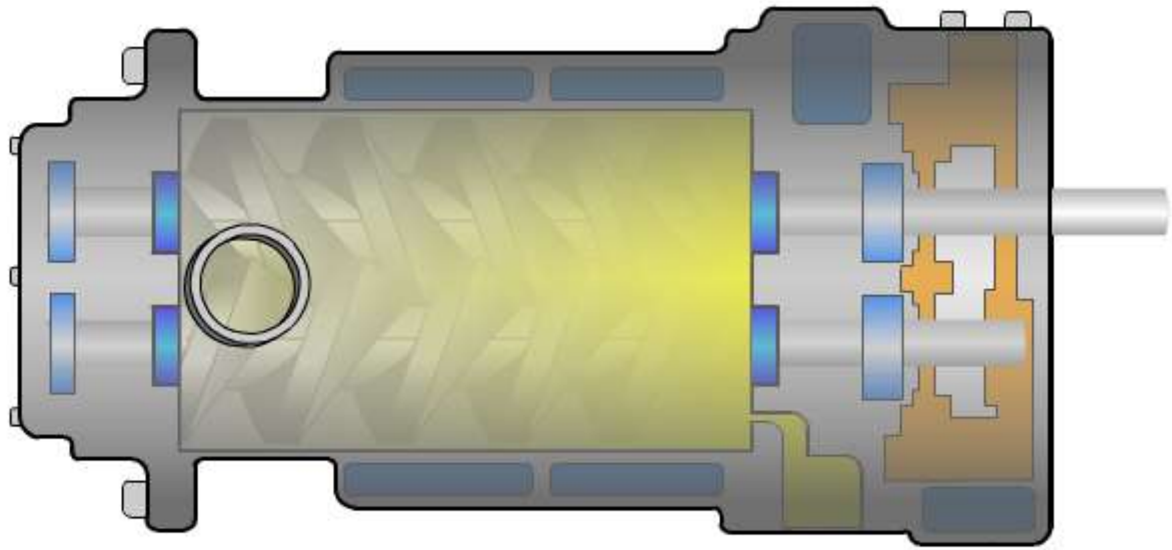


Screw Mechanism



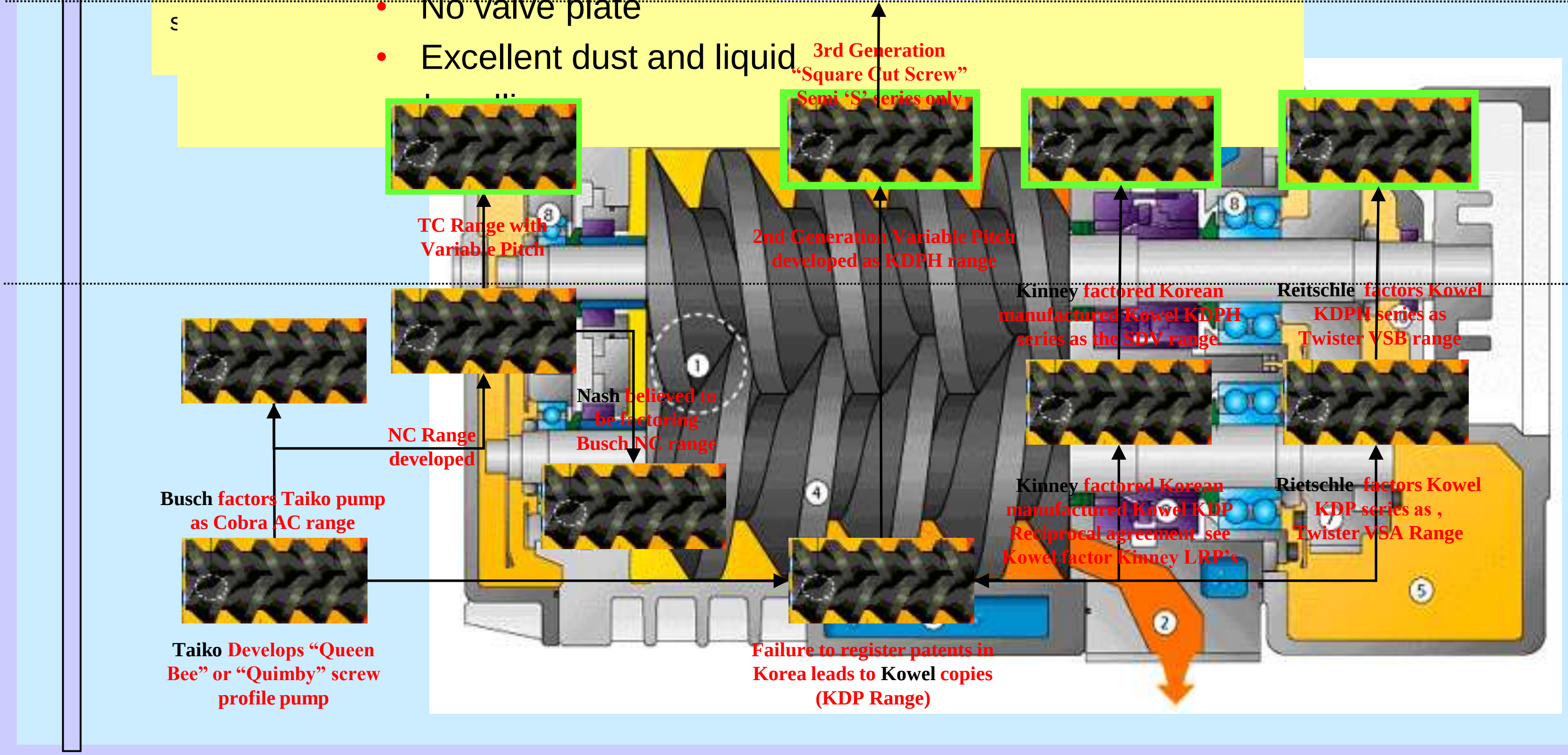
Comprises opposing synchronously rotating screws

Screw

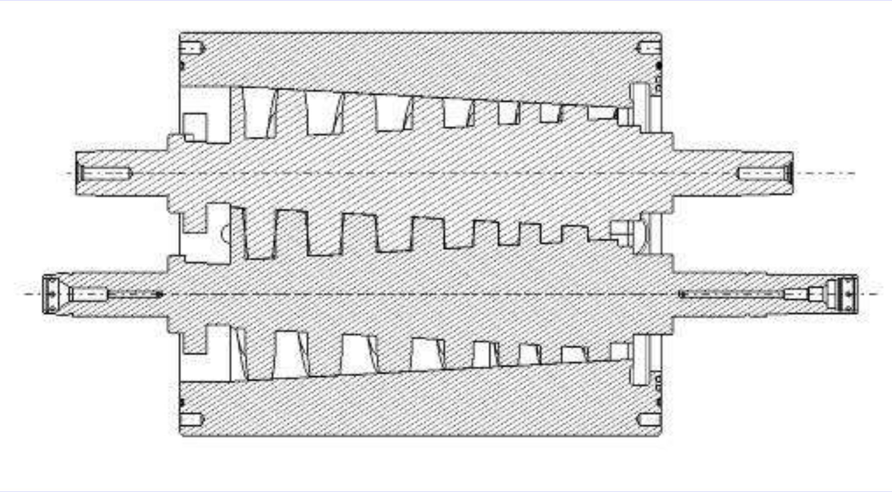
- Excellent handling of solid material
- Progressive compression
  - With tapers, variable pitch etc.
  - No sudden re-expansion until final exhaust port
- Compression “trajectory” can be designed
- Can be scaled up to moderately large capacities
- Tip clearance critical to overall performance
  - Direct “line of sight” from outlet to inlet
  - Performance can depend on “history” (temperature, flow)
- Clearances controlled at “whole pump level”
- More difficult to make small capacity machines / machines with small exhaust stages?

Screw Generation Technologies

- Third generation
  - Square screw form
    - Easier to machine on mill turn using standard end mills
    - Gradual compression
    - No porting
    - No valve plate
    - Excellent dust and liquid handling

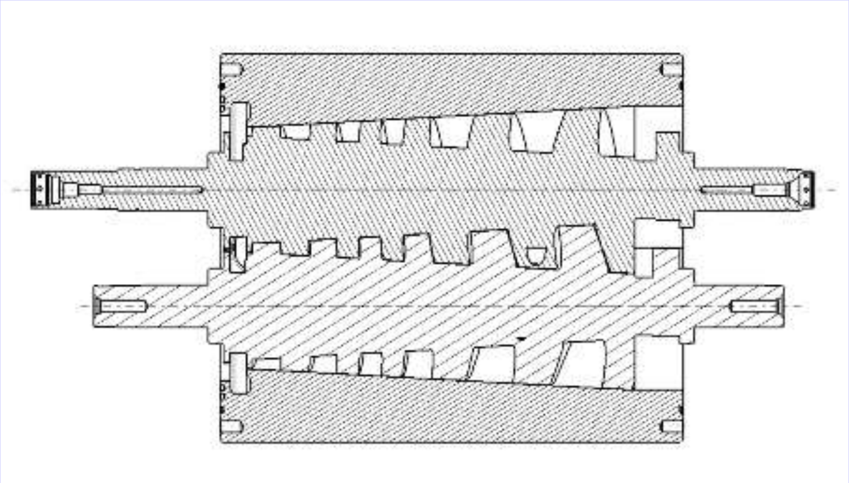


Square Screw Design



- Stepped changes of pitch – don't blend into each other so harder to manufacture
- Tapered design
- Discrete variable pitch for good thermal control
- Tip leakage limits pitch & hence swept volume – compromises light gas performance

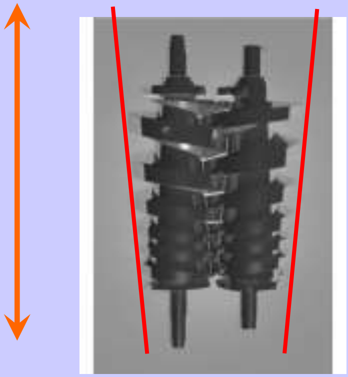
Tapered Quimby



- No limit to the length of pitch
- Greater throughput can be achieved using Quimby screw in the same stator as a square screw
- Conjugate screw form – good sealing hence relatively good light gas performance
- ‘Discrete variable pitch for good thermal control
- More expensive to manufacture than square form

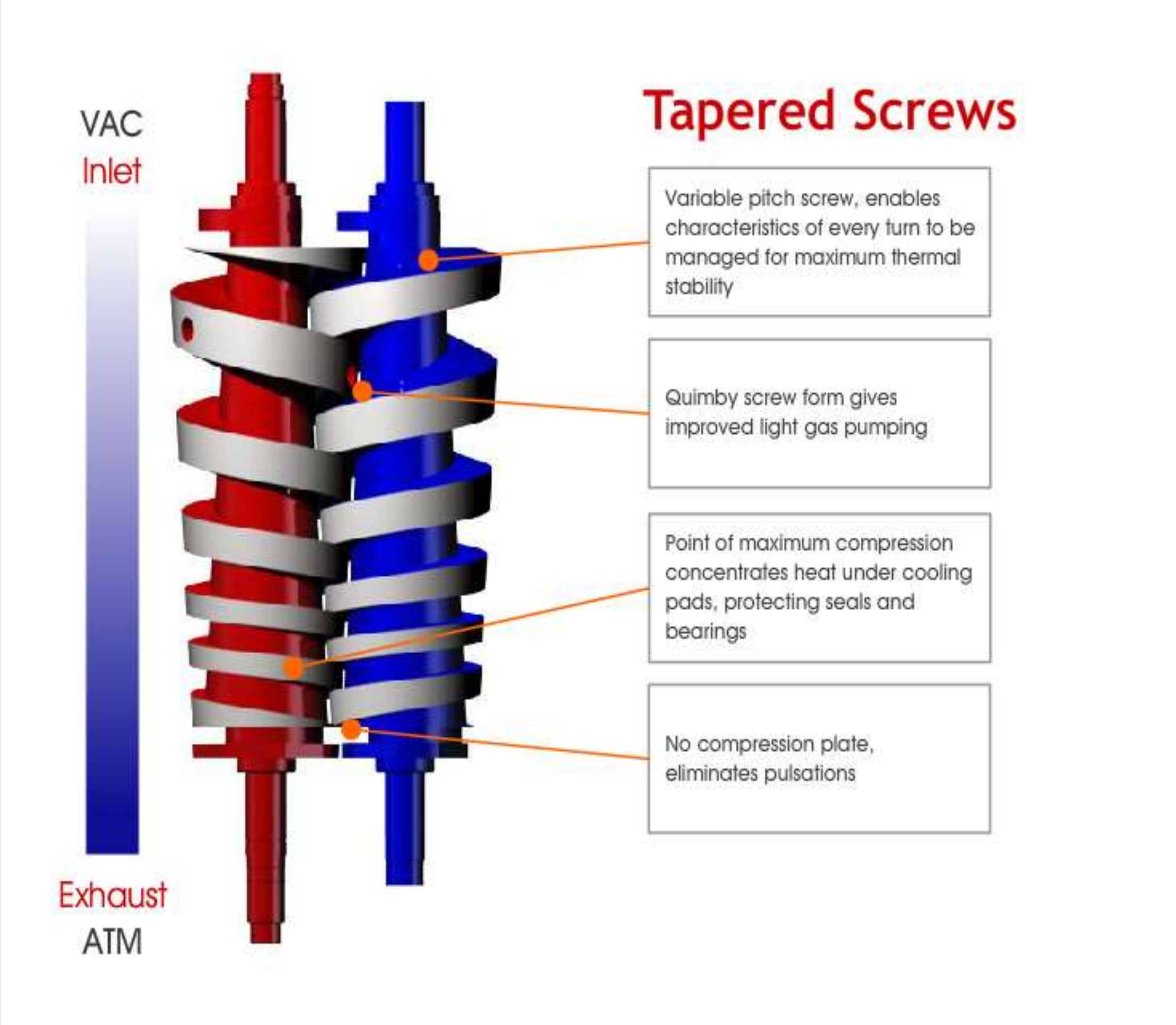
Screw Machines

Screws



Tapered screws for tight clearances without coatings.

Screws not matched pairs



Finally

- Thanks to Edwards for information and illustrations
- However, presentation and any errors or omissions are entirely my responsibility