Working Theory of Power Steering Pump

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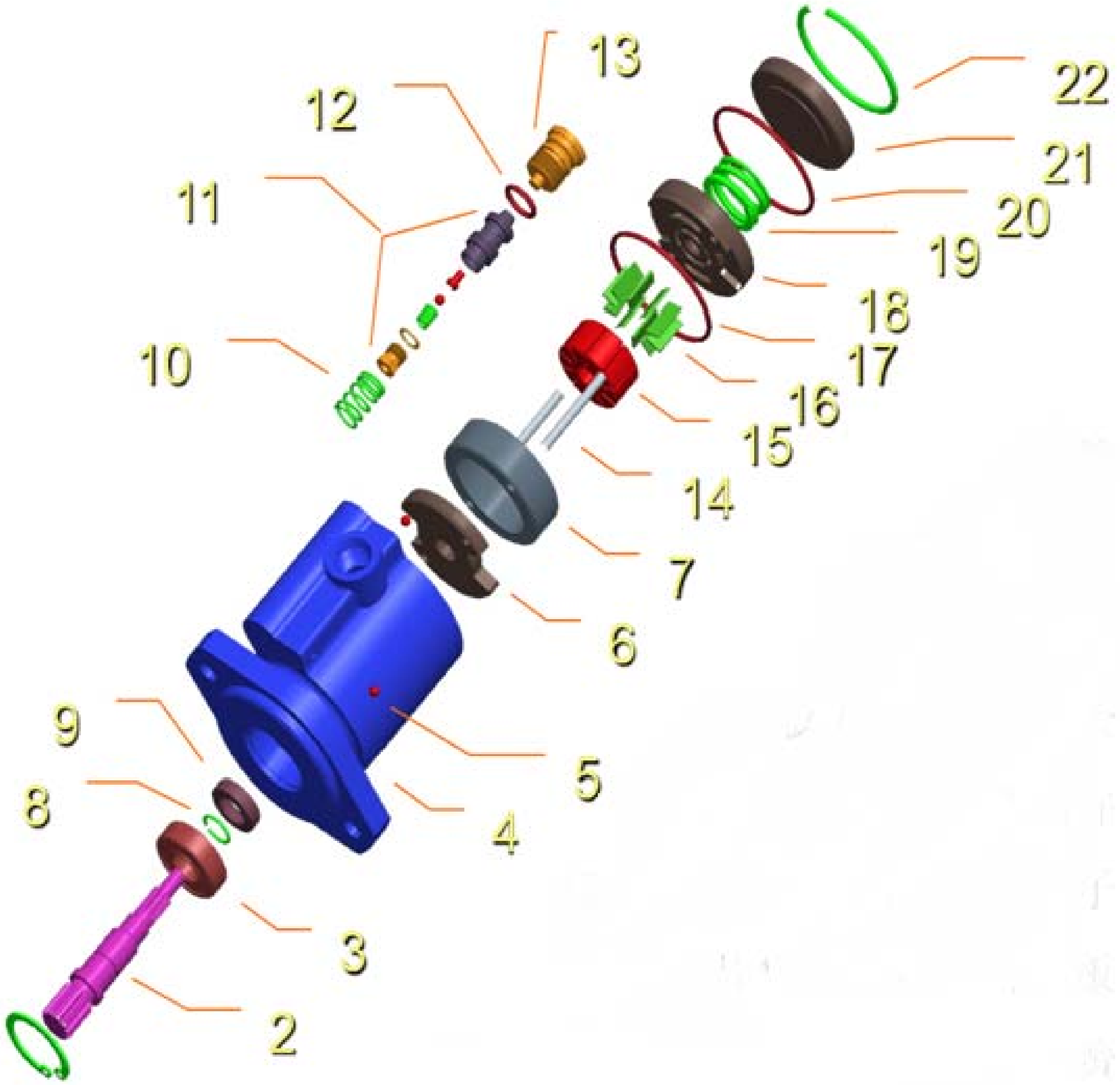
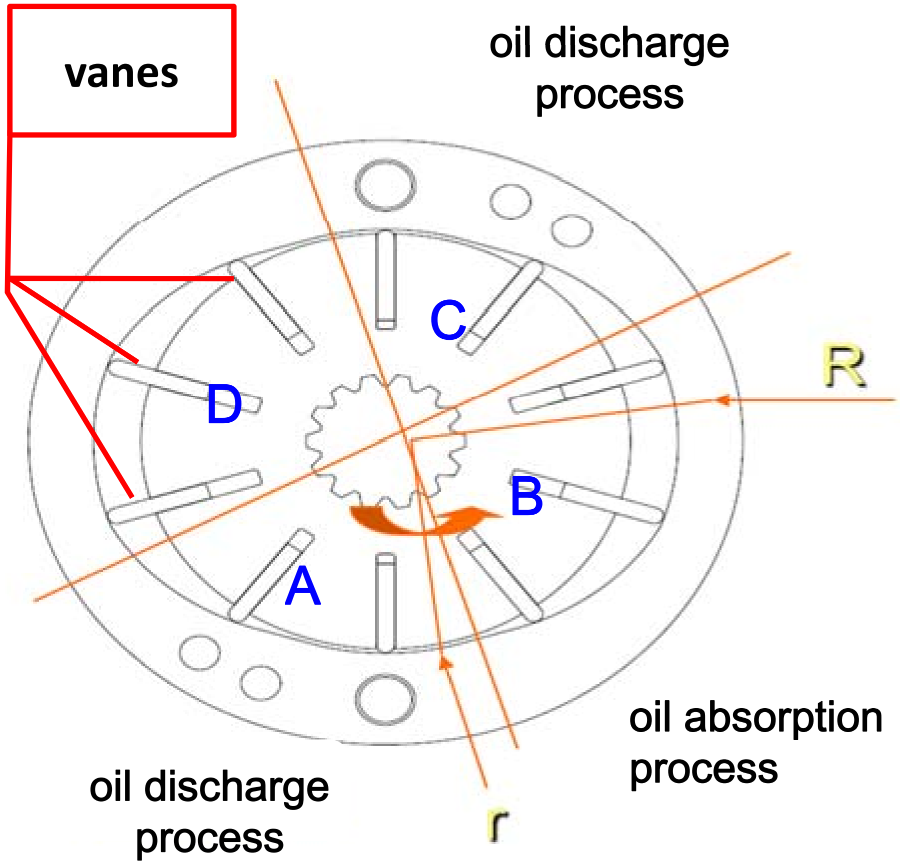
- Hydraulic power steering system of vehicle is widely used in domestic, benefiting from its long history and mature technology. At least 95% power steering of vehicles are hydraulic. As a safety part of power steering system , power steering pump is also widely used.

- As power source of power steering system, the hydraulic power steering pump uses the engine as transmission medium, transforming the mechanical energy into hydraulic energy, then power steering gear transform the hydraulic energy into mechanical energy, making the driver’s steering earlier and the vehicle’s maneuverability better.

Steering Vane Pump Structure



1. 卡簧：	Retaining ring
2. 轴：	Shaft
3. 轴承：	Bearing
4. 泵体：	Housing
5. 钢球：	Steel ball
6. 侧板：	Side plate
7. 定子：	Cam ring
8. 轴卡簧：	Snap ring
9. 油封：	Oil seal
10. 弹簧：	Spring
11.滑阀组件：	Sliding valve
12.O型圈：	O-ring
13.阀堵：	Valve plug
14.定位销：	Location pin
15.转子：	Rotor
16.叶片：	Vane
17.O型圈：	O-ring
18.压力板：	Pressure plate
19.弹簧：	Spring
20.O型圈：	O-ring
21.后盖：	Cover
22.弹簧：	Retaining ring



● Currently, the vane pump is typical, whose working theory is the same with the normal double-acting vane pump.

● The cam ring camber is composed of two big arcs with radius “R” (area B and D), two small arcs with radius “r” (area A and C) , and smooth curves that connect them together. “R” is larger than “r” .

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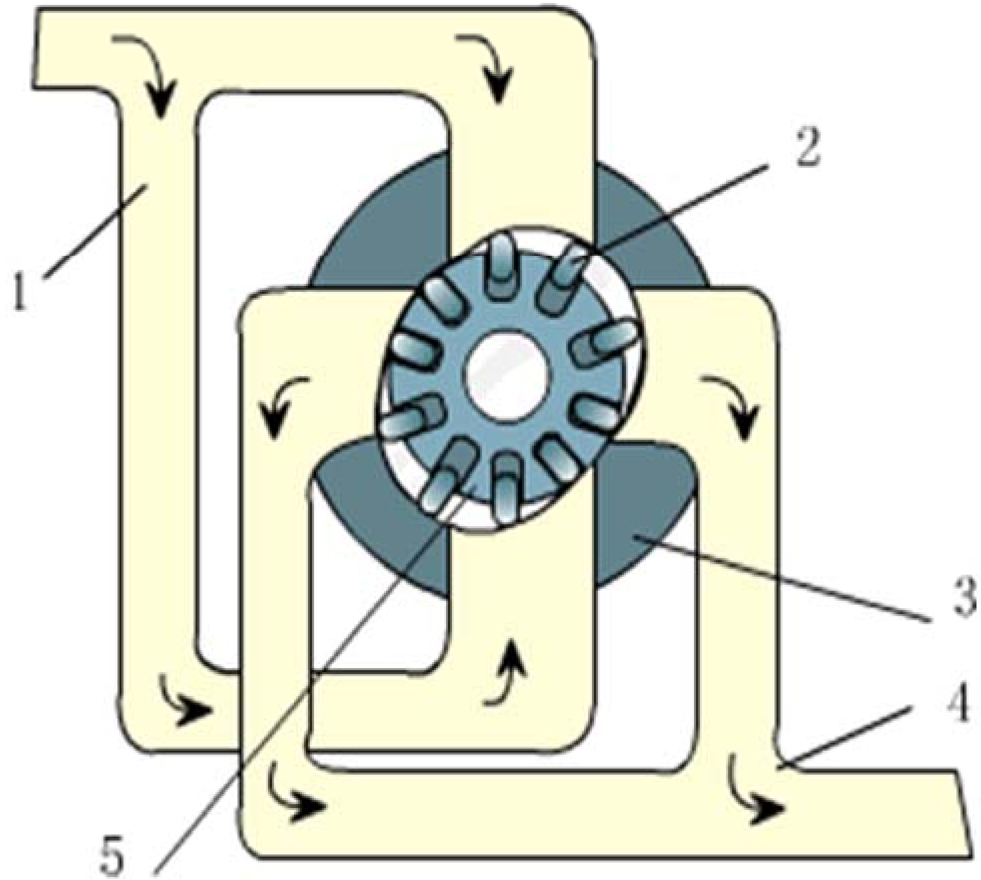

1. oil absorption process

2. vanes

3. cam ring

4. oil discharge process

5. rotor

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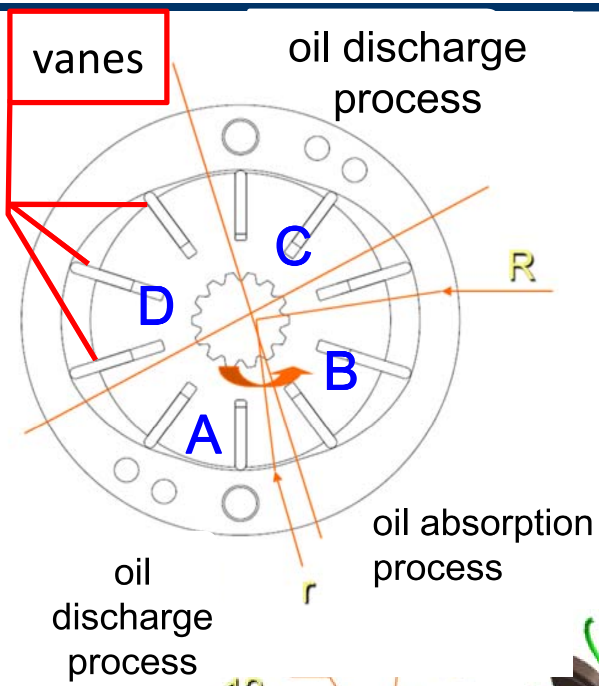

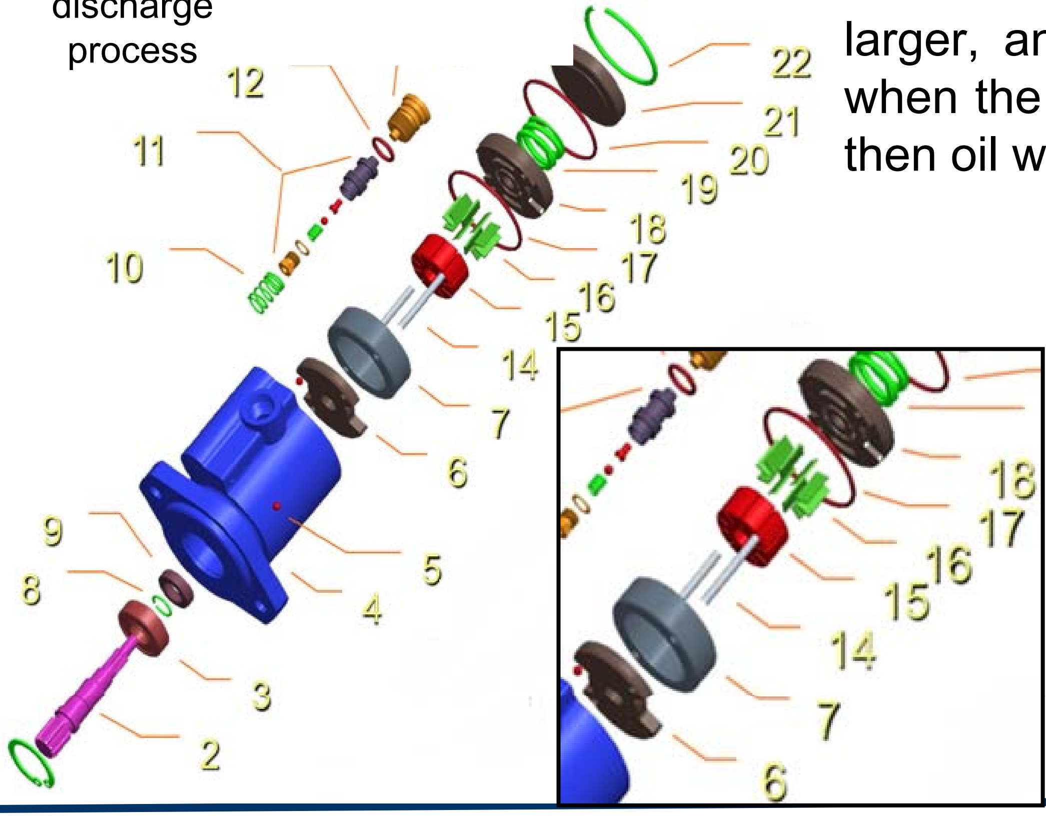

● The vanes 16 can slide inside of the groove of cam ring 7. The rotor 15, cam ring 7 and vanes 16 are covered between the two oil plate (side plate 6 and pressure plate 18).

● When the vanes are sliding, they will close to the inside surface of the cam ring result from the centrifugal force, then the absorption cavity and discharge cavity will be separated for the sealing function between vanes and inside surface. When the vanes slide from A to B, which is also the radius from “R” to “r”, then the volume between two vanes will be larger, and oil will be absorbed from inlet hole of oil plate. when the vanes slide from B to C, the volume will be smaller, then oil will be discharged through outlet oil of oil plate.

● If the rotor finishes one revolution, the vanes will finish two process/cycles, which is from oil discharge to oil absorption. That is so called double-acting vane pump.

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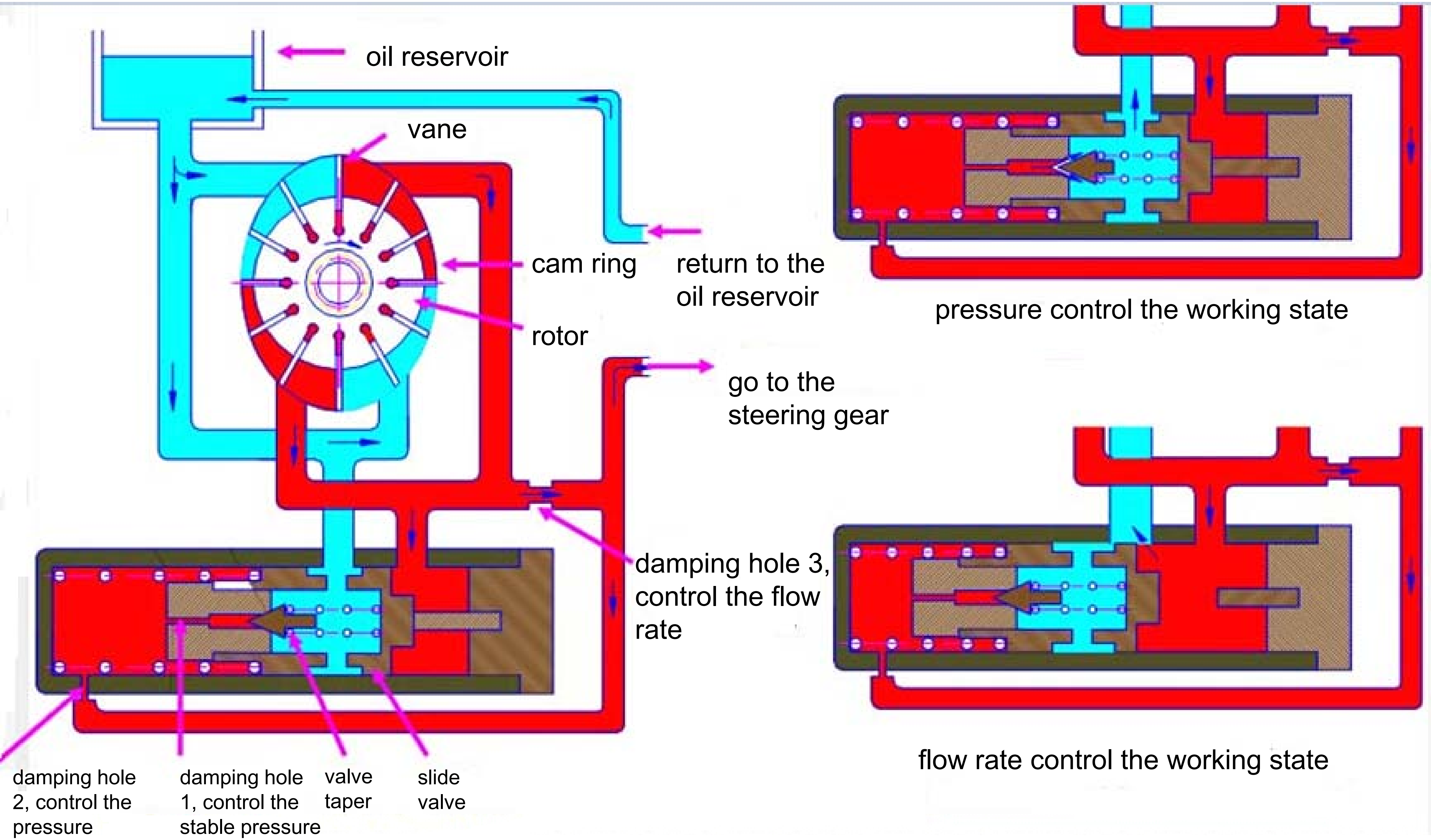
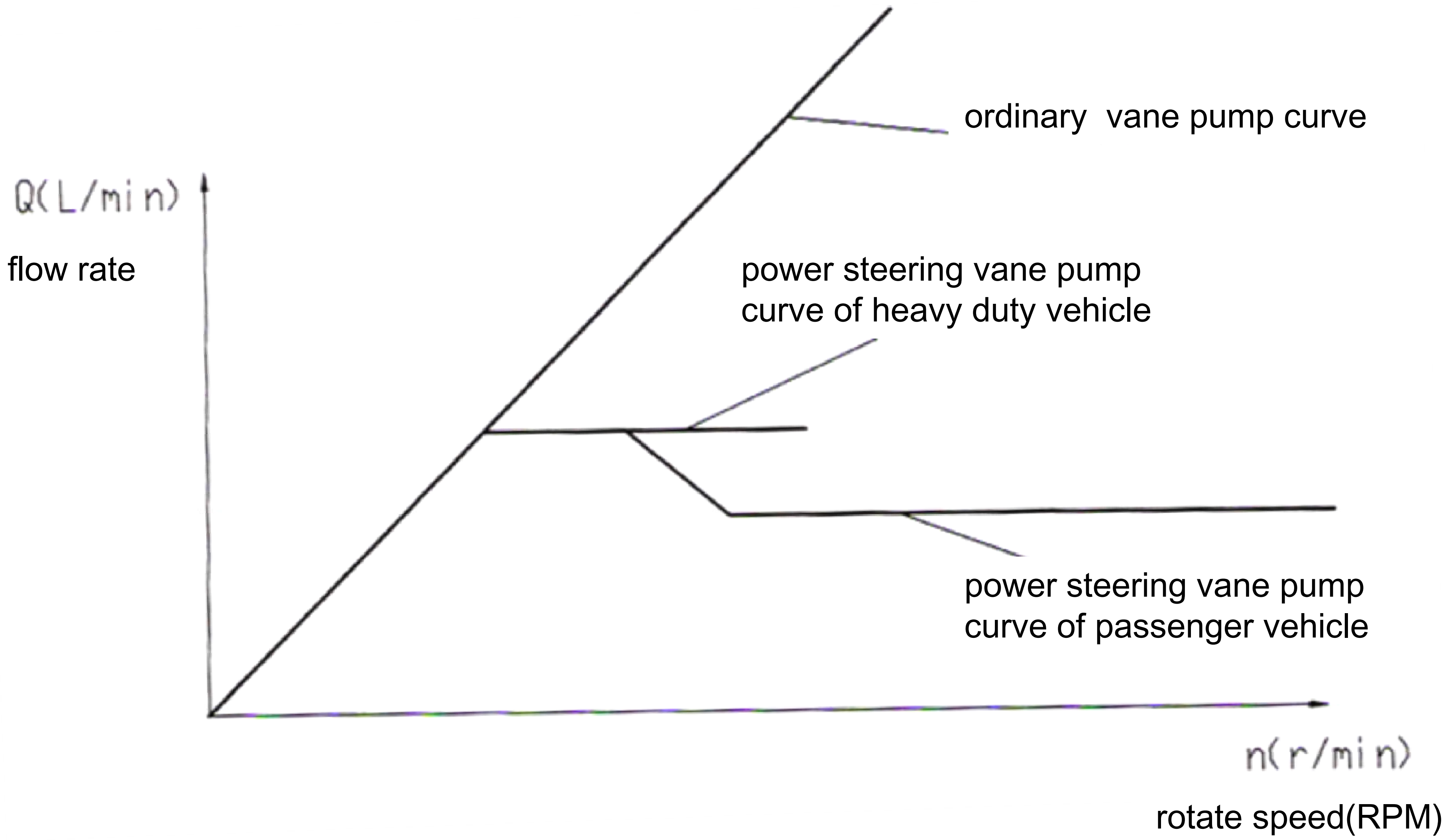


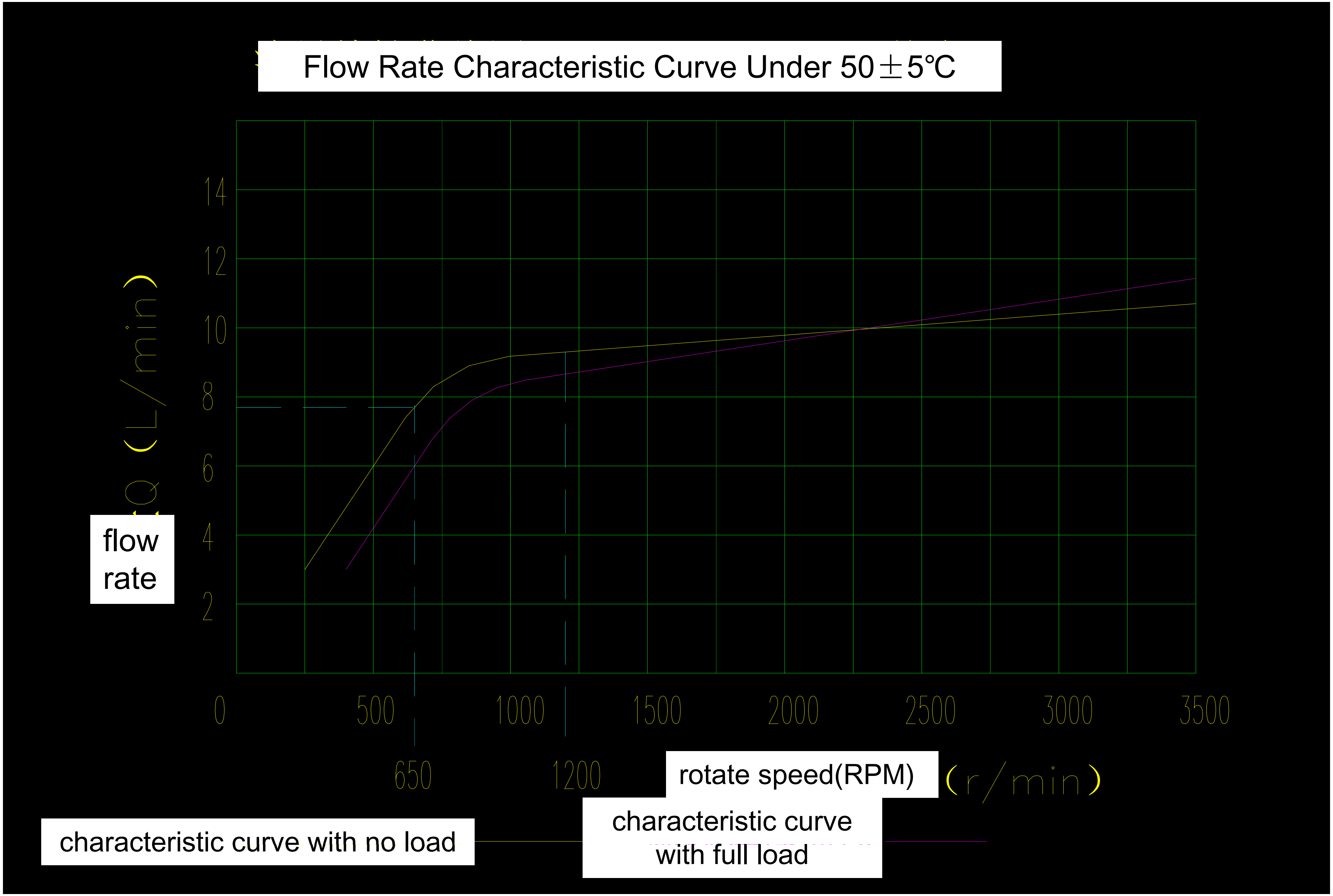
- There is overflow valve and pressure safety valve in the power steering pump. When the pump is working, its sliding valve has a certain degree of opening, making the flow rate meets requirement and making the redundant flow rate back to absorption chamber of the pump.

- If steering system pressure over the maximum working pressure of the pump, then the sliding valve will be open totally, then all the pressure oil will be back to the absorption chamber, which will protect the whole system.

Different Flow Rate Characteristic Curve of Different Vehicles



Flow Rate Characteristic Curve of QX Pump of Commercial Vehicles



Porthole throttling：

Control the flow rate through setting a contractive tube in a certain continuous hydraulic flow, and the modes of throttling are as below:

- **Porthole tube with short length**（薄壁孔节流）: $Q=88.6CQf\triangle P^{0.5}$

characteristic：

L/d ≤0.5

The flow rate is in direct proportion to the square root of differential pressure. And this will have no much relation with the oil temperature.

- **Porthole tube with long length**（细长节流体）: $Q=(144d^4/rvL)\triangle P$

characteristic：

L/d ＞4

The flow rate has linear relation with the differential pressure.

And this will be effected by the oil temperature largely.

- **Short tube throttling**（管节流）: $Q=88.6CQf\triangle P^{0.8}$

characteristic：

L/d ＞0.5 ～4

The flow rate is in direct proportion to the 0.8 power (0.8次方) of differential pressure. And its effect from oil temperature will between the first two modes.

- **Ring-type throttling**（环形缝隙节流）: $Q=(\pi dh^3/12UL)\triangle P$. This mode is out of date now.

partial pressure loss of throttling porthole：

$\Delta P=\xi.\rho.v^2/2$

ΔP--- pressure loss, MPa.

ξ--- local resistance coefficient, coming from the test.

ρ--- density of liquid, kg/m^3 .

v--- average flow rate, m/s.

Notice： just use the formula of $\Delta P \propto v^2$ when design the throttling porthole.

equilibrium equation （平衡方程） of two ends of valve core：

left end（P－ΔP）A＋k.x＝P.A , right end.

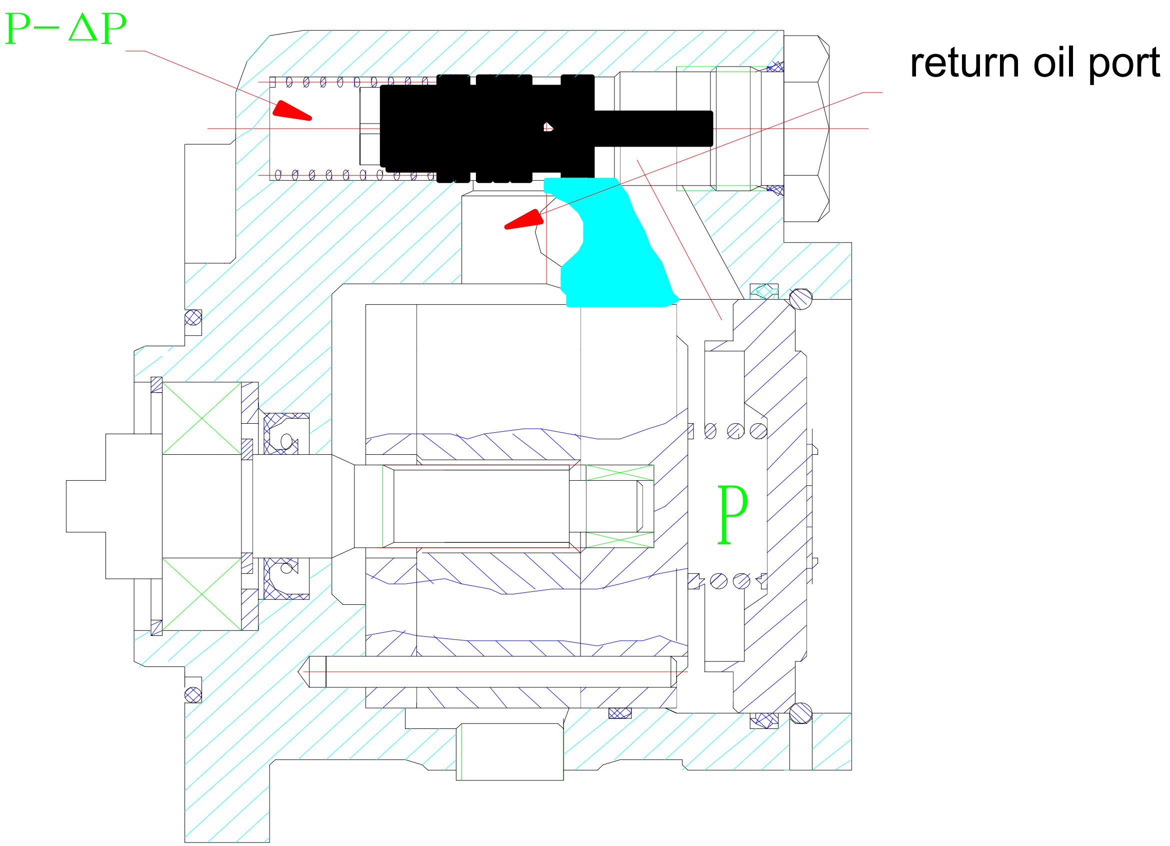
P--- pressure of inner cavity of pump, MPa.

A--- sectional area of valve core, which is $\pi D^2/4$, mm^2 .

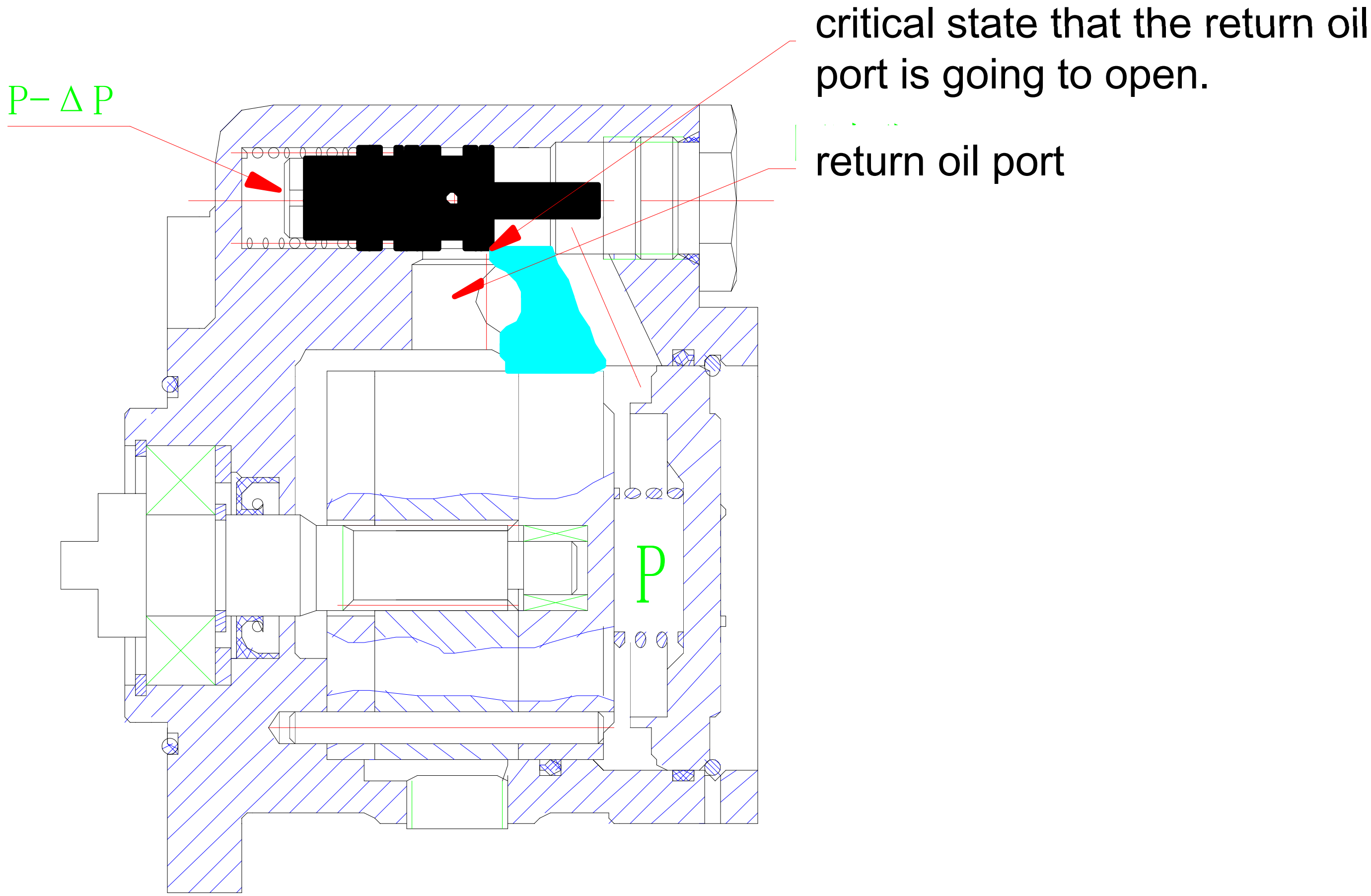
K--- stiffness coefficient of spring, N/mm.

X--- compression amount of spring, mm.

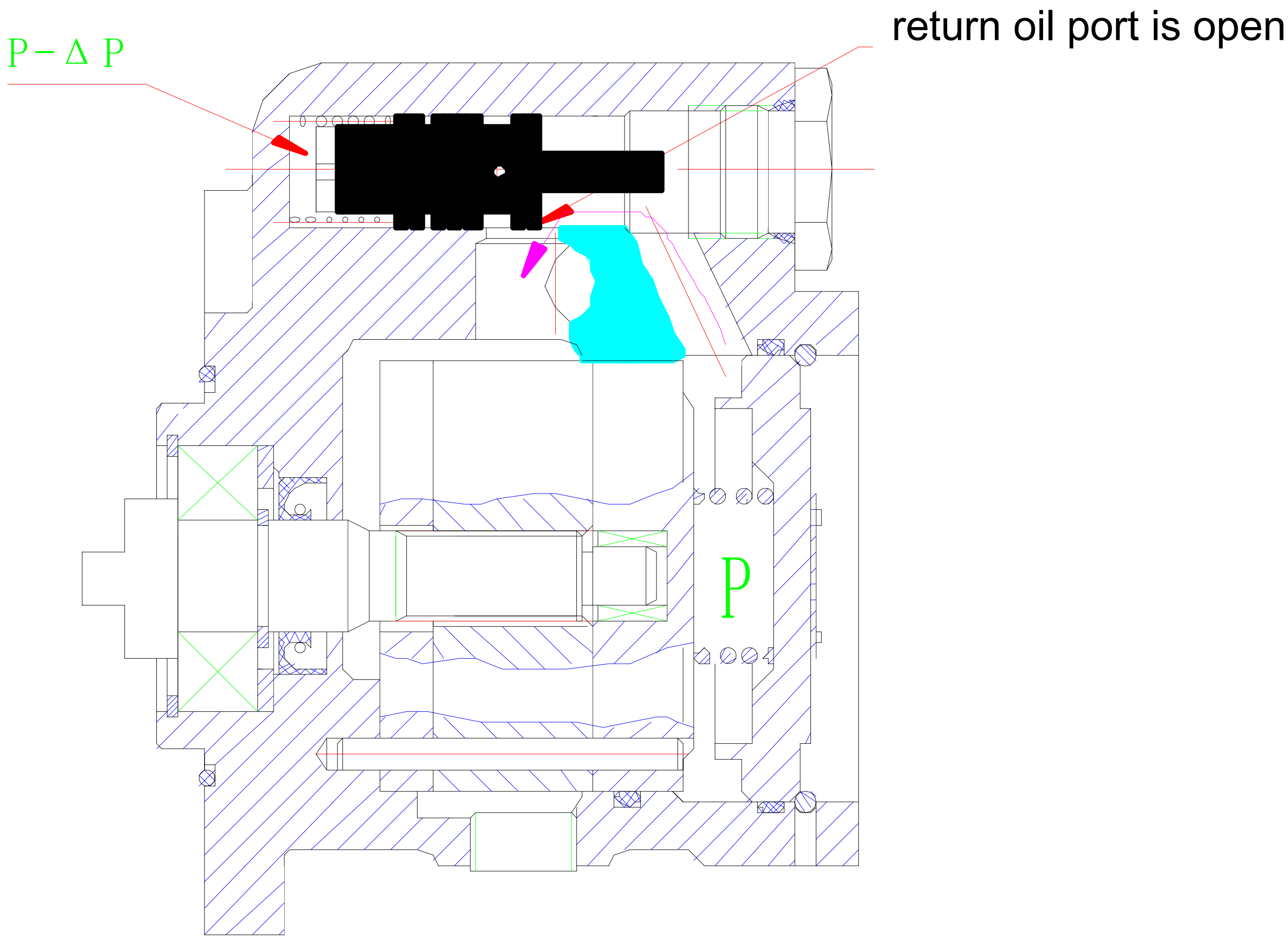
When the rotate speed of pump is low, then the output flow rate will be also low, meaning the average flow rate “**V**” is also low, which will make the produced “**ΔP**“ is not enough to overcome the spring force, then the valve core will be in the right end, and return oil port will be closed.



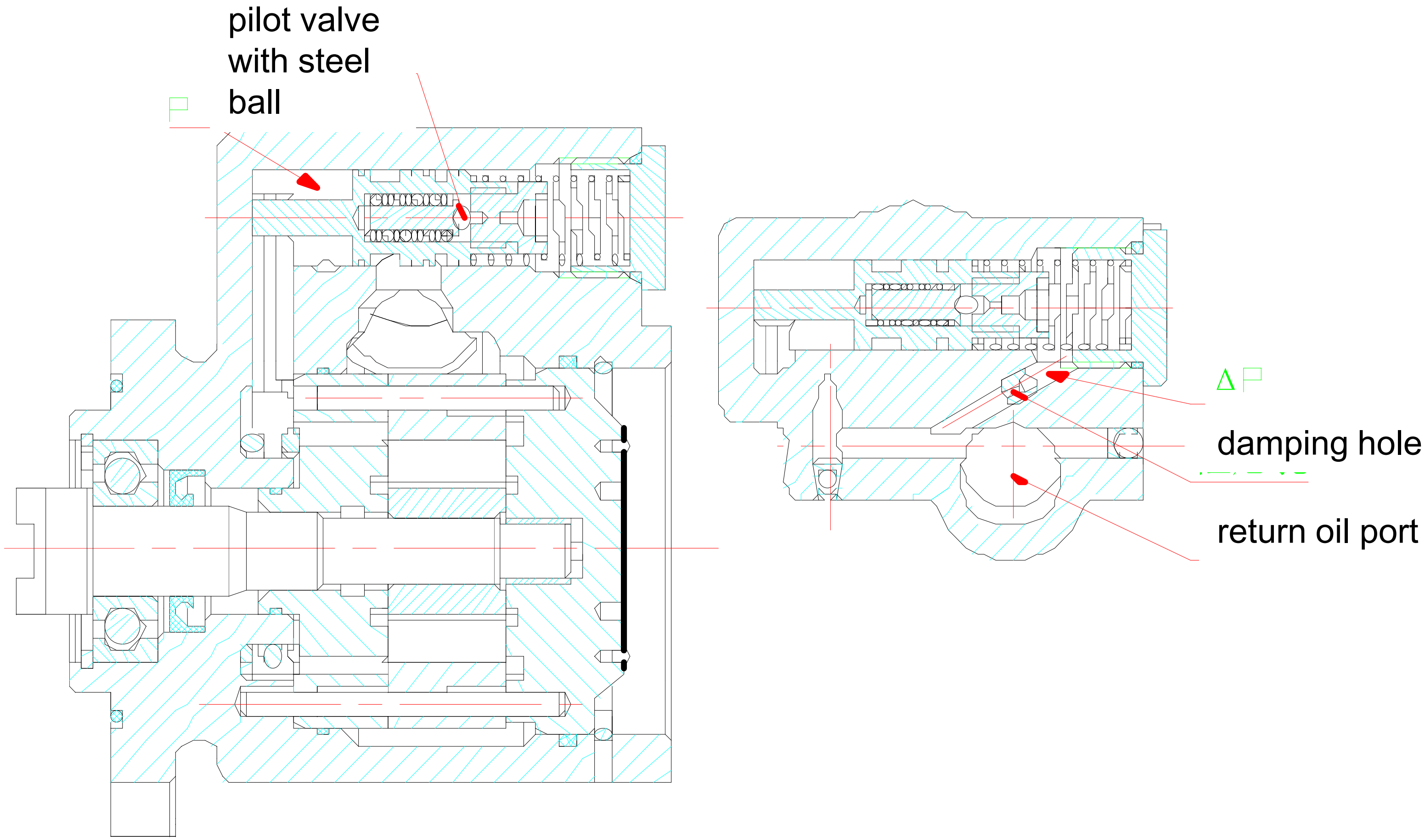
With the rotate speed is of pump increasing, then the output flow rate will be also become larger, meaning the average flow rate “**V**” is increasing, which will make the produced “**ΔP**” is large enough to overcome the spring force, then the valve core will move in left direction. The critical state and status before it, will be reflected in the linear part （ straight line portion ） of flow rate characteristic curve.



With the rotate speed of pump is much higher, then the output flow rate and the average flow rate “**V**” will be also become large enough, which will make the produced “**ΔP**” is large enough to open the return oil port, then the oil over flow will happen. This is reflected in the part of flow rate characteristic curve after inflection point.



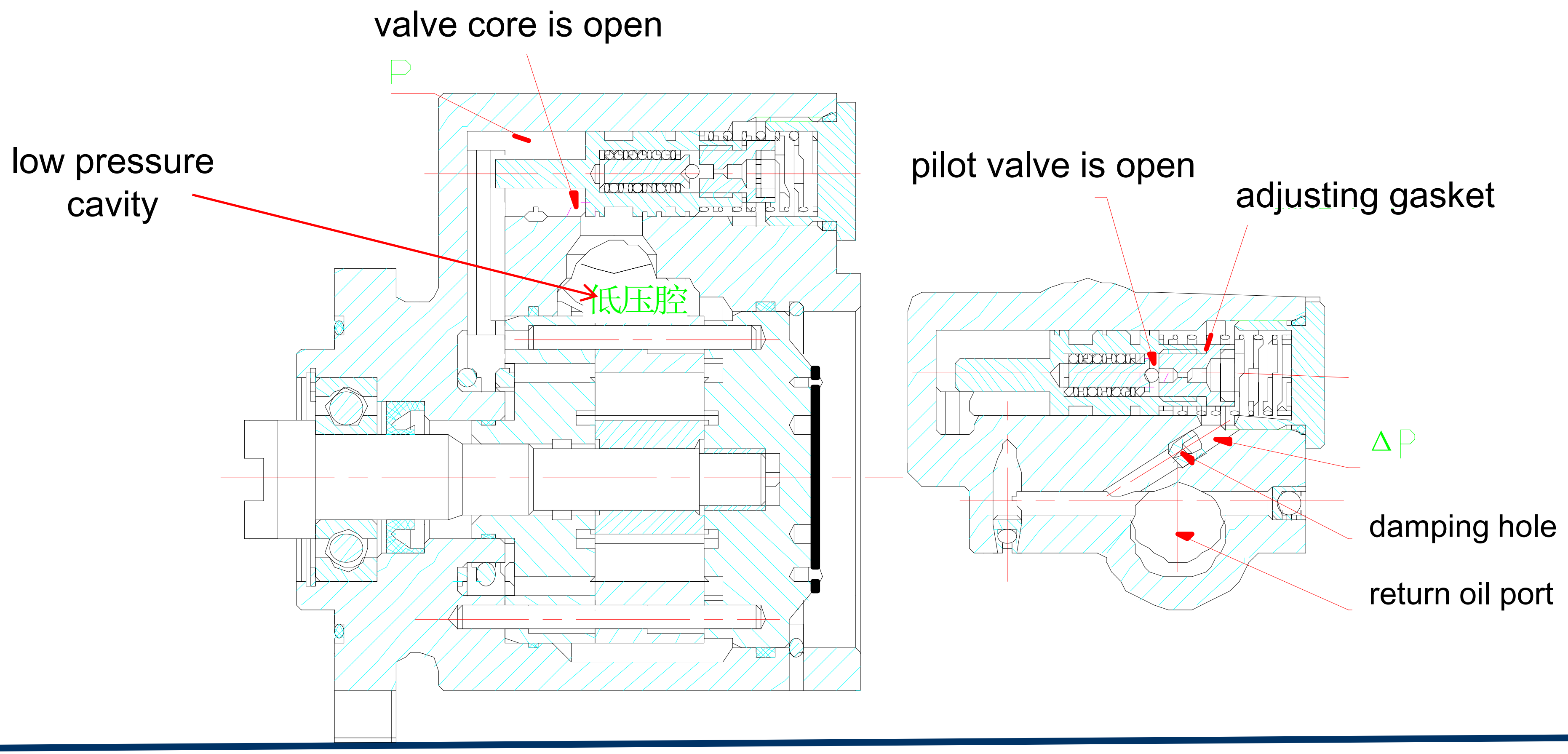
If the return oil port/line is not close, then the system pressure, which is on the steel ball valve, will not overcome the force of pilot valve spring, and the valve will be in close status, and “ΔP” is zero (ignore the pressure loss results from the flow rate).



Adjustment Process of Pressure

- If the return oil port/line is lose, then the output flow rate will be zero, and the system pressure will increase quickly, overcoming the spring force of pilot valve, and the valve will be open. When the oil goes through the damping hole, then "ΔP" will not be zero, making the valve core open and to be in the equilibrium position.

- Because of very small damping hole, even small flow rate under very low rotate speed will make very large enough "ΔP" , consequently, there is no necessary relationship between the pressure and rotate speed.

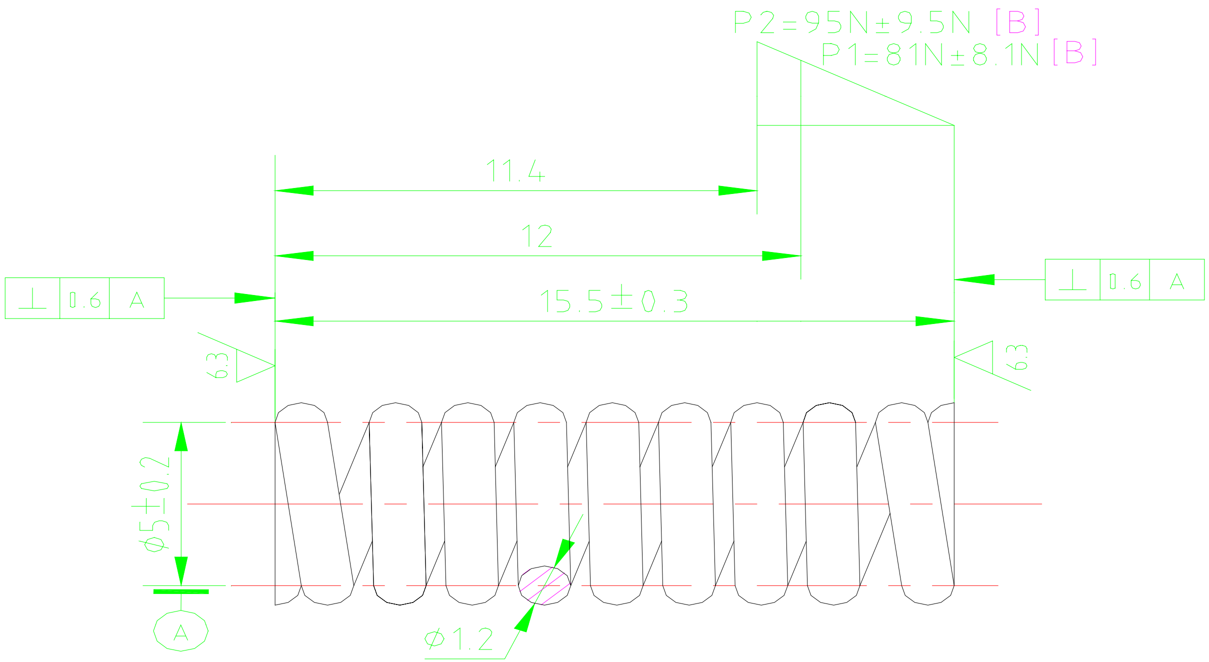


Relationship Between Pressure Adjustment and Flow Rate Adjustment

- Equilibrium equation of force is the same, but the position of producing "ΔP" is different.
- Both of them use the valve core to adjust.
- When the flow rate is being adjusted, the pilot valve will be closed, and no oil goes through the spring of valve core, resulting in no pressure loss "ΔP" in the damping hole. Just use the pressure loss "ΔP" produced by throttling porthole to adjust the flow rate.
- When the pressure is being adjusted, the return oil port/line will be closed, and output flow rate is zero. Then there is very few flow rate goes through the throttling porthole, and the corresponding produced pressure loss can be ignored. Consequently, just need to consider the pressure loss from damping hole, and adjust the valve core.
- The maximum pressure can be adjusted through changing the quantity of adjusting gasket.

Requirements of springs:

- Grinding the two end faces of spring into flat, and the flat surface should not less than ¾ circles.
- Tempering.
- Oxidation treatment for surface.
- Stretch, compress, and twist the spring until it has good working stress and residual stress but without permanent deformation.
- Surface cleanliness is ≤0.5mg.



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