SEOUL NATIONAL UNIVERSITY

NuTHEL
Nuclear Thermal Hydraulic Engineering Lab.

원자로 열유체 실험 (9)

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과제-2 관련

- 동영상도 함께 제출
- 촬영 조건 기술
  - ✓ 셔터스피트, 조리개, 조명 환경 등
- 영상에 대한 분석 추가
  - ✓ 예: 팝콘 상승 속도, 풍선 표면 요동 전파 속도 등

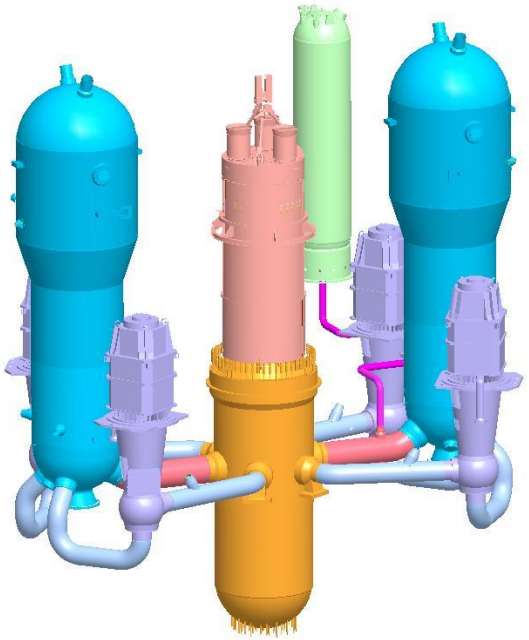
과제-3: 기포 실험 (3주)

- Pool scrubbing, filtered ventilation system, suppression pool, sparger
- Test data analysis
  - ✓ Void fraction, bubble and liquid velocity: comparable with published results?
  - ✓ Bubble terminal velocity
- Conventional method vs. BubCNN
  - ✓ BubCNN, BubGAN
- Bubble measurement sensors: 4-sensor conductance probe, optical fiber probe
- PIV, fluorescent particle, high pass filter

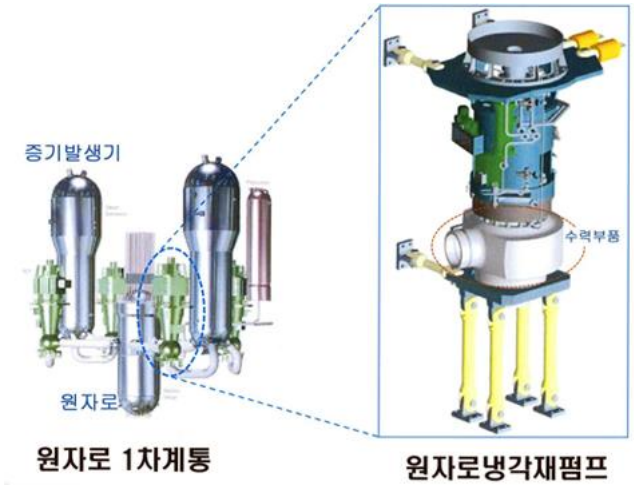
- Zigzag motion
  - ✓ http://typo3.ims-tuhh.org/fileadmin/user_upload/PDF.pdf
  - ✓ https://www.sciencedirect.com/science/article/pii/S1385894717301286
  - ✓ https://link.springer.com/article/10.1007/s11053-019-09537-x
  - ✓ https://arxiv.org/pdf/1810.08757.pdf
- CFD simulation
  - ✓ STAR-CCM+ tutorial
  - ✓ https://onlinelibrary.wiley.com/doi/full/10.1002/eng2.12100

유체기기

- **원자력 발전소 내 유체기기**
  - ✓ **1차계통: 원자로 냉각재 펌프**
  - ✓ **2차계통: 펌프, 터빈, 압축기 등**
  - ✓ **가스냉각로: 압축기**

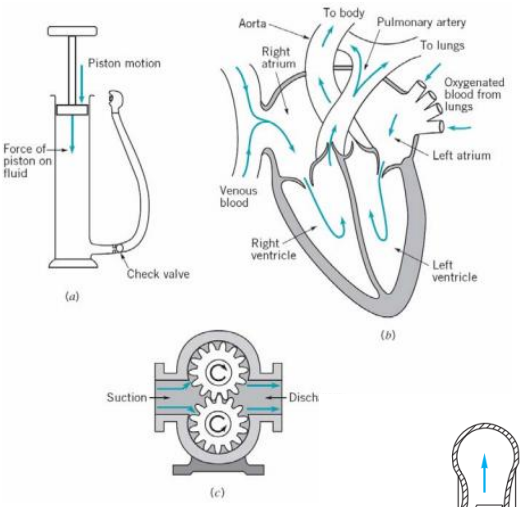


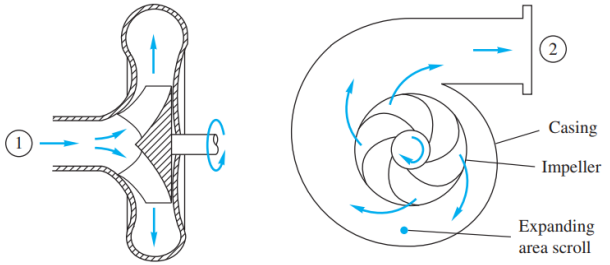
- **열수력 실험의 유체기기**
  - ✓ **펌프, 송풍기 (blower), 압축기 (compressor)**
    - 유체 이송, 열수력 실험장치 제작 시 필수

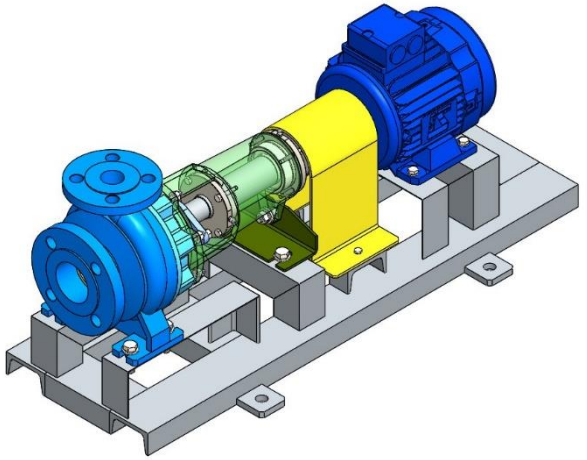


펌프

- Function
  - ✓ Add energy to the fluid
  - ✓ Do work on the fluid
- Fluid : liquid
- Cavitation
  - ✓ An important design consideration
- Positive-displacement pumps (PDPs)
- Dynamic pumps
  - ✓ Add momentum to the fluid
  - ✓ Using fast-moving blades or vanes
  - ✓ Converts its high velocity
    to a pressure increase
    by exiting into a diffuser section



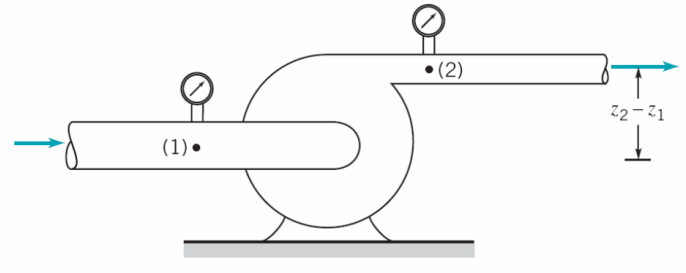


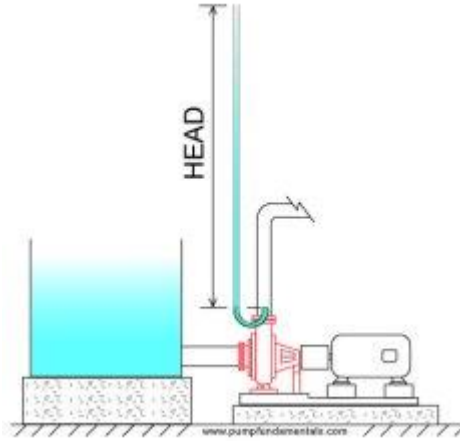


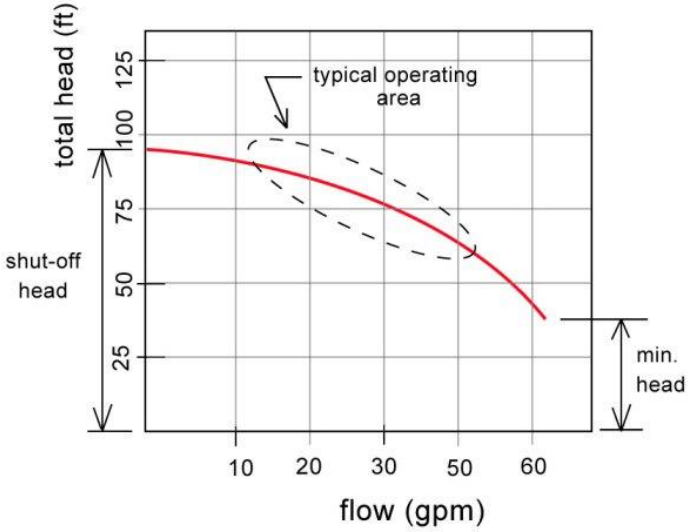
펌프

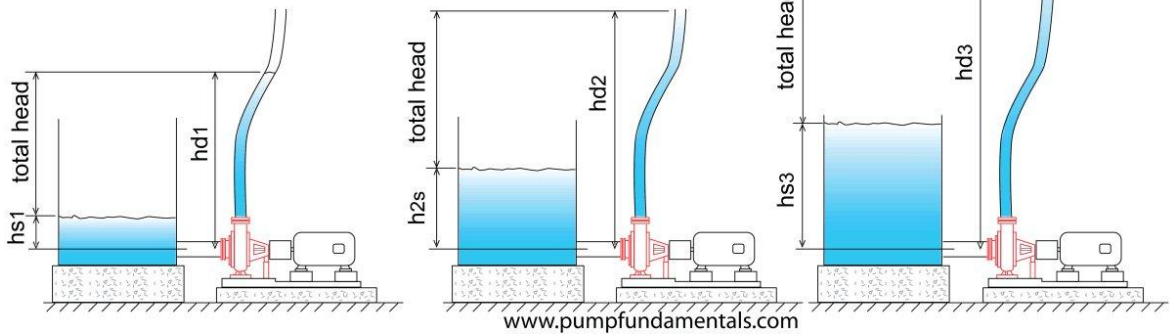
❖ Head

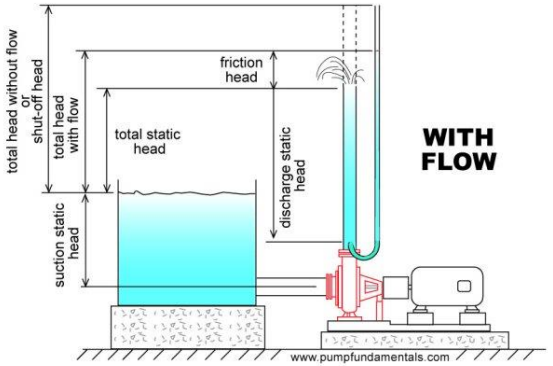
- ✓ The height at which a pump can raise water up
- ✓ To buy the correct pump for your application you first have to know what total head you need and at what flow rate.





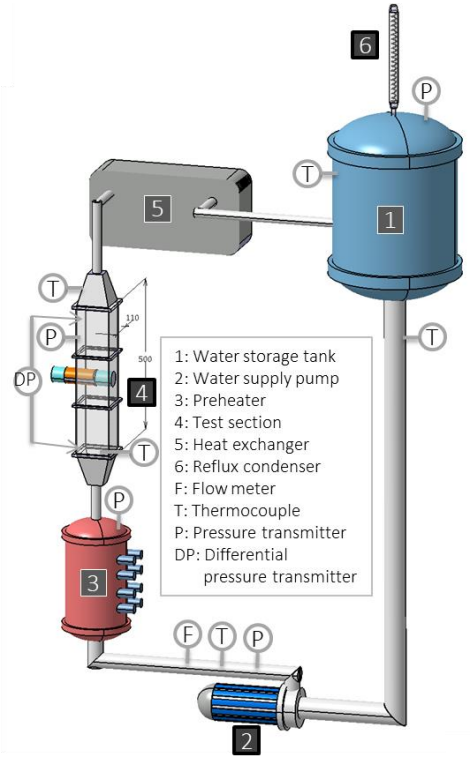


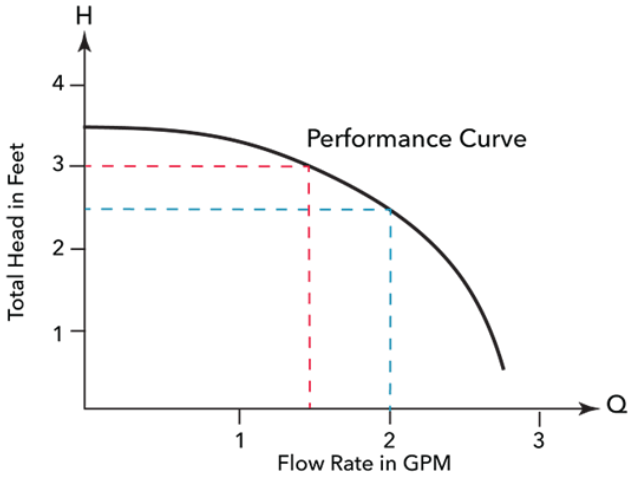




펌프

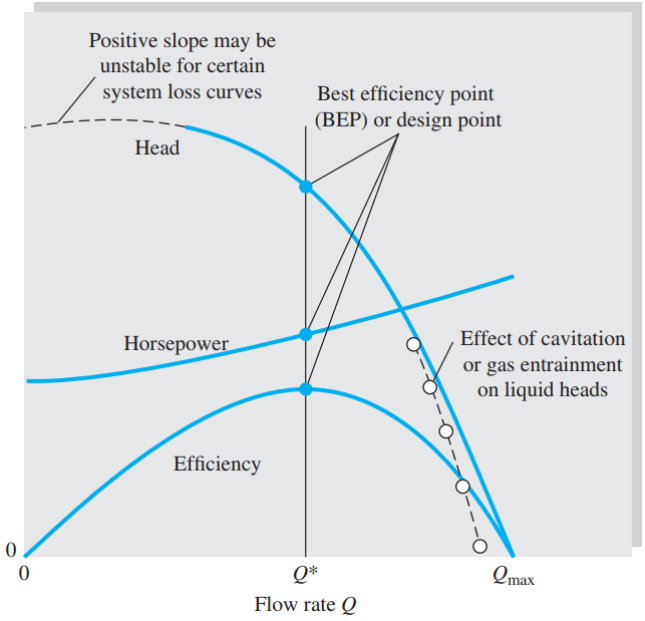
- **Selection of a pump (for a heat transfer test facility)**
  - ✓ **Determine the flow rate**
    - Heat removal : $\dot{q} = \dot{m} c_p (T_{out} - T_{in})$
    - Mass flow rate : $\dot{m} = \rho Q = \rho v A$
  - ✓ **Estimate the pressure drop**
    - Hydraulic head
    - Frictional pressure loss
    - Form pressure loss
  - ✓ **Compare the flow rate and pressure drop with the pump's performance curve**

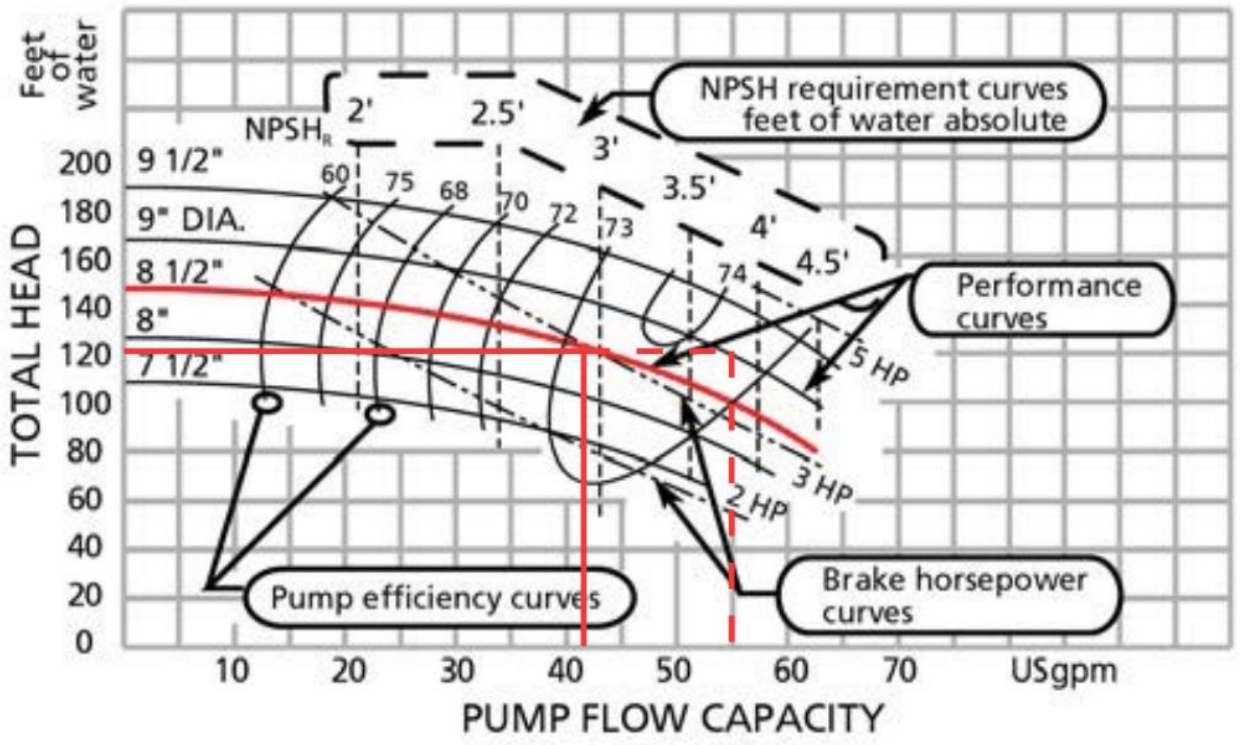




펌프

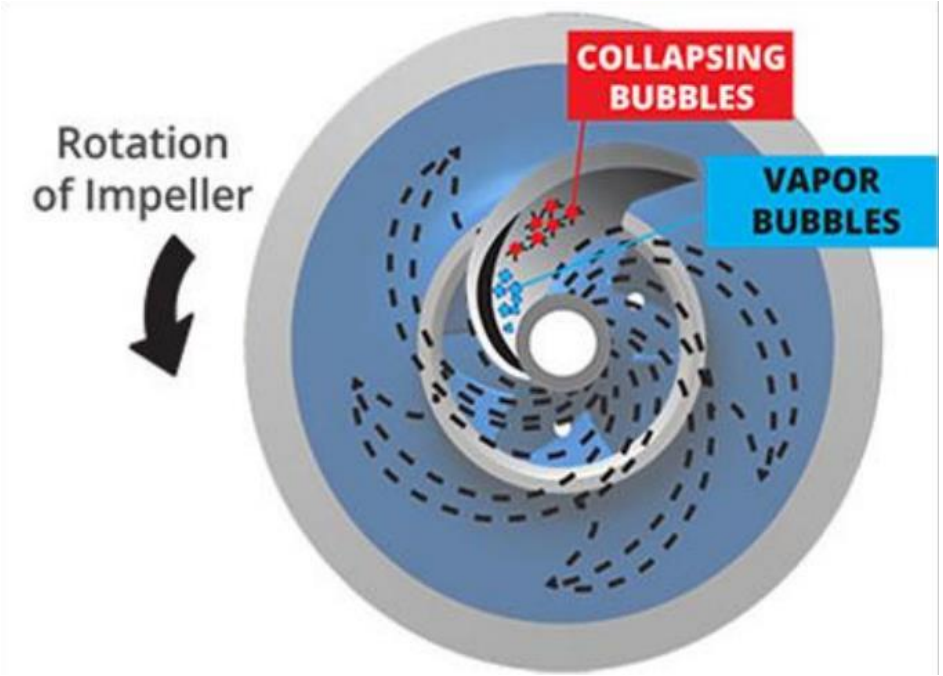
- **Pump performance curve**
  - ✓ Q vs. head H, brake horsepower (bhp), and efficiency η
  - ✓ Design flow rate Q & best efficiency point (BEP)

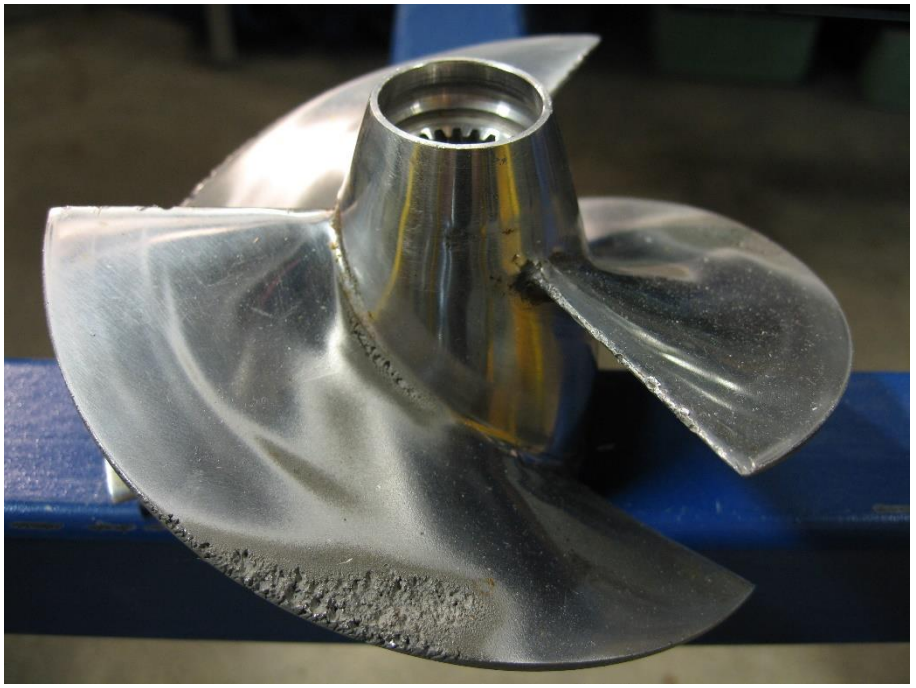




펌프

- **Net positive suction head**
  - ✓ **On the suction side of a pump**
    - Low pressure → cavitation within the pump
    - When the liquid pressure at a given location is reduced to the vapor pressure of the liquid
  - ✓ **Vapor bubbles form → loss in efficiency + structural damage to the pump**





펌프

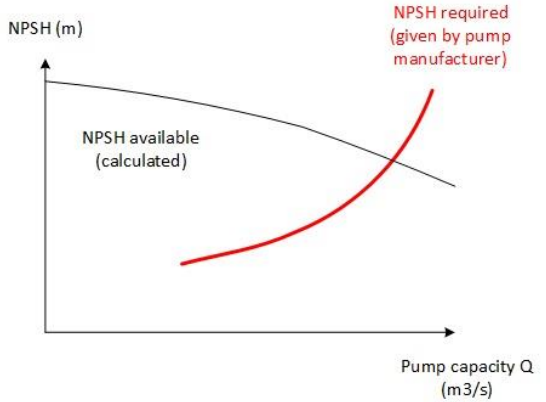
❖ Net positive suction head

✓ Head required at the pump inlet to keep the liquid from cavitating

$$\text{NPSH} = \frac{p_i}{\rho g} + \frac{V_i^2}{2g} - \frac{p_v}{\rho g}$$

$$\text{NPSH} = \frac{p_a}{\rho g} - Z_i - h_{fi} - \frac{p_v}{\rho g}$$

(when pump inlet is placed at a height Zi above a reservoir whose free surface is at pressure p_a)



- Equal or greater in actual system to avoid cavitation

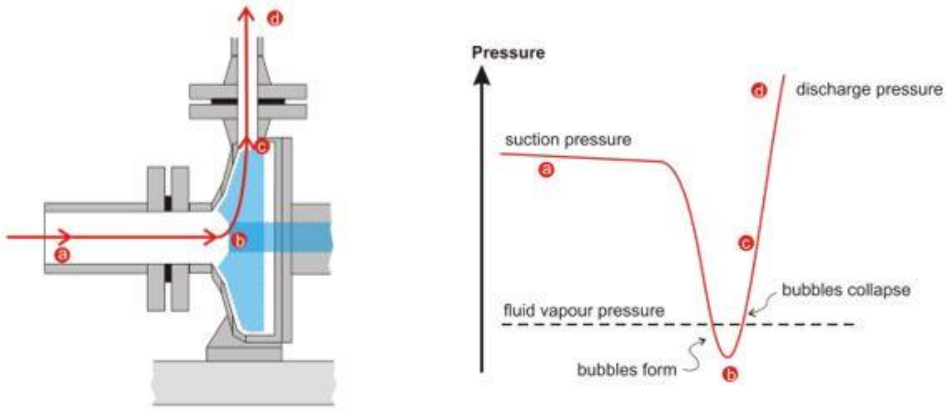
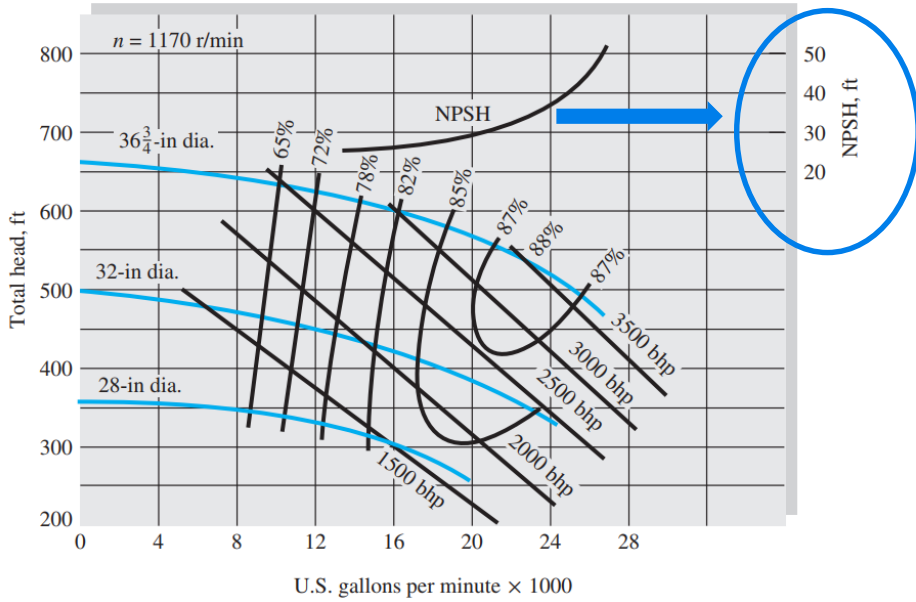


Figure 1. Pressure gradient through a centrifugal pump experiencing cavitation: fluid enters the pump (a); pressure drops below vapour pressure at impeller (b), pressure rises as fluid passes out to discharge (d) and bubbles condense and collapse (c).



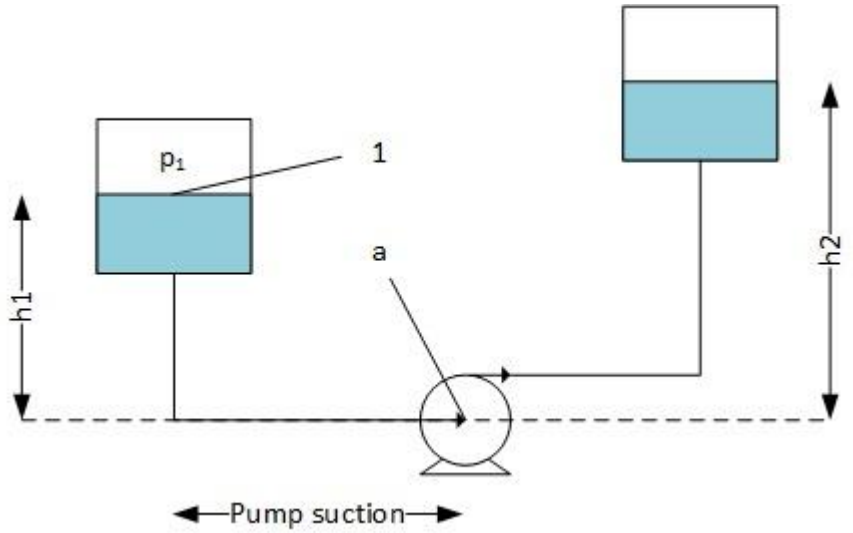
펌프

❖ Net positive suction head

✓ Head required at the pump inlet to keep the liquid from cavitating

$$\mathrm{NPSH} = \frac{p_i}{\rho g} + \frac{V_i^2}{2g} - \frac{p_v}{\rho g}$$

$$\mathrm{NPS}H = h_1 + \frac{p_1 - \mathrm{p}_v}{\rho g} + \frac{{u_1}^2}{2g} - \left|\Delta H_f\right|_1^a$$



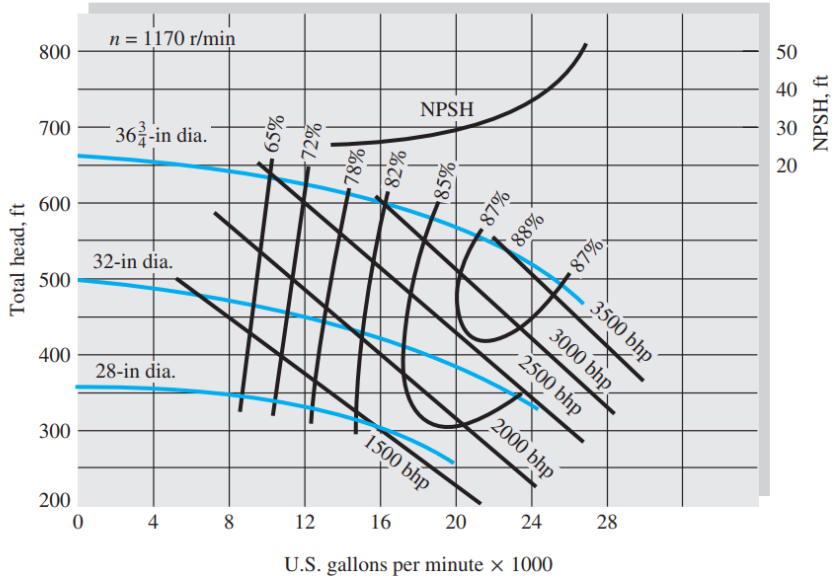
Q=10 m^3/h.
D=60 mm
h1= 2 m, Twater= 20oc.

STEP 1 : calculate the liquid vapor pressure
For water at 20c : 2339 Pa.
STEP 2 : calculate the velocity in pipe
The velocity is $10/(\pi*0.06^2/4)$= 3536 m/h = 0.98 m/s.
STEP 3 : calculate the NPSH
NPSH = $2+(101325-2339)/(9.81*998)+0.98^2/(2*9.81)+0=2+10.11+0.05=12.16$ m

❖ Net positive suction head

EXAMPLE 11.2

The 32-in pump of Fig. 11.7*a* is to pump 24,000 gal/min of water at 1170 r/min from a reservoir whose surface is at 14.7 lbf/in^2 absolute. If head loss from reservoir to pump inlet is 6 ft, where should the pump inlet be placed to avoid cavitation for water at (*a*) 60°F, $p_v = 0.26$ lbf/in^2 absolute, SG = 1.0 and (*b*) 200°F, $p_v = 11.52$ lbf/in^2 absolute, SG = 0.9635?



For either case read from Fig. 11.7*a* at 24,000 gal/min that the required NPSH is 40 ft. For this case $\rho g = 62.4$ lbf/ft^3. From Eq. (11.20) it is necessary that

$$\text{NPSH} \le \frac{p_a - p_v}{\rho g} - Z_i - h_{fi}$$

or

$$40 \text{ ft} \le \frac{(14.7 - 0.26 \text{ lbf/in}^2)(144 \text{ in}^2/\text{ft}^2)}{62.4 \text{ lbf/ft}^3} - Z_i - 6.0$$

or

$$Z_i \le 27.3 - 40 = -12.7 \text{ ft} \qquad \textit{Ans. (a)}$$

The pump must be placed at least 12.7 ft below the reservoir surface to avoid cavitation.

For this case $\rho g = 62.4(0.9635) = 60.1$ lbf/ft^3. Equation (11.20) applies again with the higher p_v:

$$40 \text{ ft} \le \frac{(14.7 - 11.52 \text{ lbf/in}^2)(144 \text{ in}^2/\text{ft}^2)}{60.1 \text{ lbf/ft}^3} - Z_i - 6.0$$

or

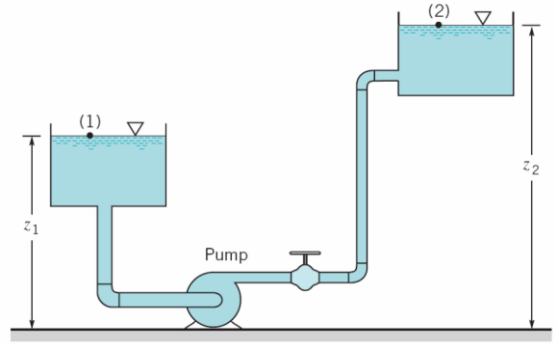
$$Z_i \le 1.6 - 40 = -38.4 \text{ ft} \qquad \textit{Ans. (b)}$$

The pump must now be placed at least 38.4 ft below the reservoir surface. These are unusually stringent conditions because a large, high-discharge pump requires a large NPSH.

펌프

❖ System Characteristics and Pump Selection

✓ The energy equation applied between points (1) and (2)



$$h_p = z_2 - z_1 + \sum h_L$$

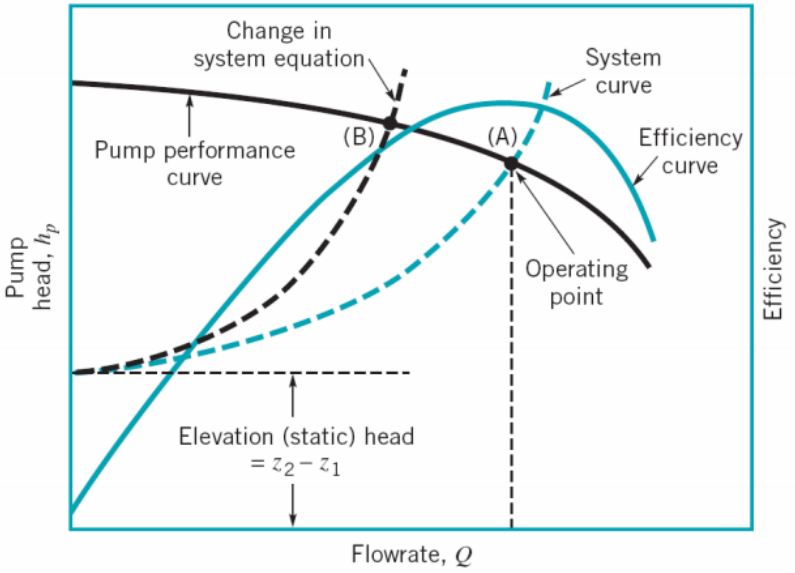
actual head gained by the fluid from the pump

All friction losses and minor losses

$$h_p = z_2 - z_1 + KQ^2$$

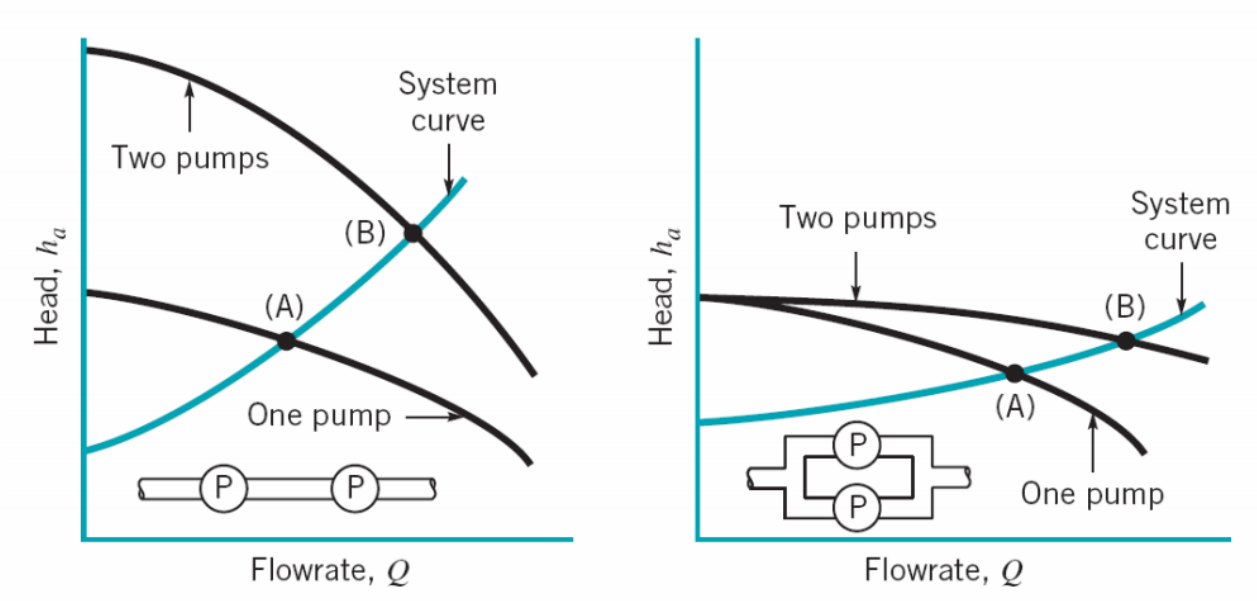
✓ K depends on the pipe size and lengths, friction factors and minor loss coefficients

✓ Pipe friction increase due to wall fouling.



펌프

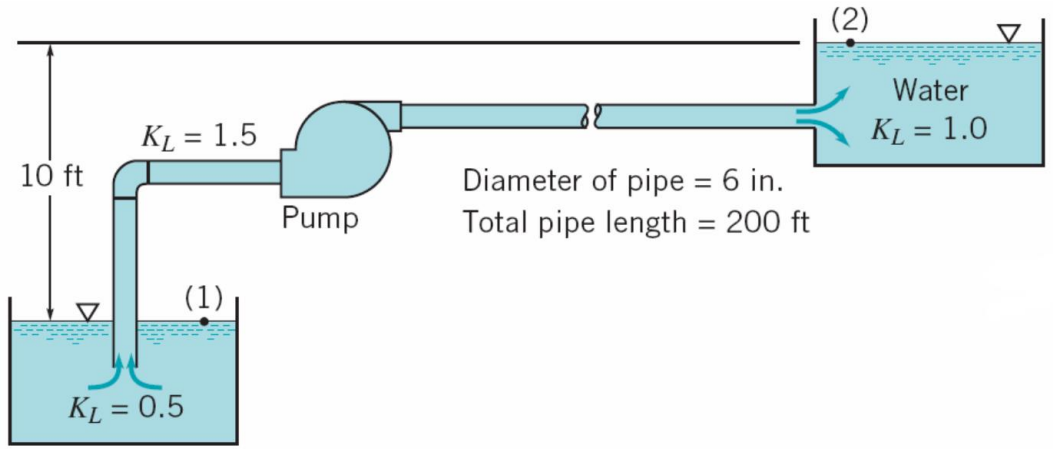
❖ Pumps in serial and parallel

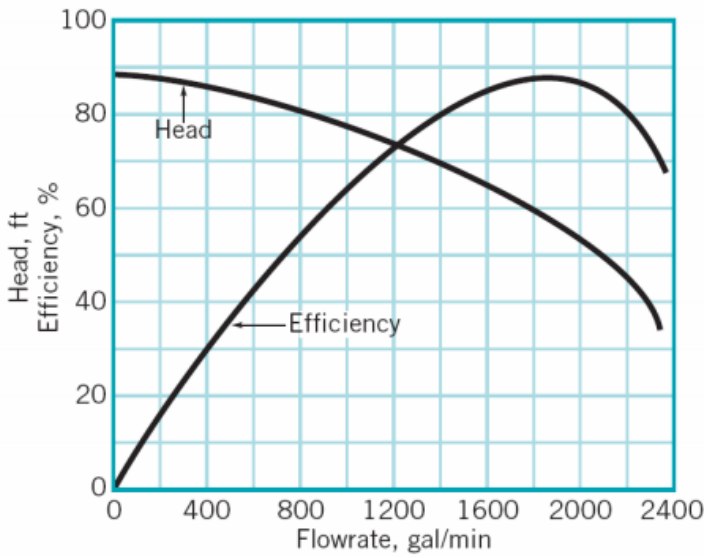


펌프

❖ Example

✓ **Water is to be pumped from one large, open tank to a second large, open tank as shown in Fig. E12.4a. The pipe diameter throughout is 6 in. and the total length of the pipe between the pipe entrance 6 in. and the total length of the pipe between the pipe entrance and exit is 200 ft. Minor loss coefficients for the entrance, exit, and the elbow are shown on the figure, and the friction factor for the pipe can be assumed constant and equal to 0.02. A certain centrifugal pump having the performance characteristics shown in Fig. E12.4b is suggested as a good pump for this flow system. With this pump, what would be the flowrate between the tanks? Do you think this pump would be a good choice? pump would be a good choice?**





펌프

❖ Example

Application of the energy equation between the two free surfaces, points (1) and (2) as indicated, given

$$h_p + \frac{p_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + f\frac{\ell}{D}\frac{V^2}{2g} + \sum K_L \frac{V^2}{2g}$$

With $p_1=p_2=0$, $V_1=V_2=0$, $z_2-z_1=10\text{ft}$, $f=0.02$, $D=6/12\text{ft}$, and $\ell=200\text{ft}$

$$h_p = 10 + \left[0.02\frac{(200\text{ft})}{(6/12\text{ft})} + (0.5+1.5+1.0)\right]\frac{V^2}{2(32.2\text{ft/s}^2)}$$

$$V = \frac{Q}{A} = .. \qquad h_p = 10 + 4.43Q^2 \qquad Q \text{ is in } \text{ft}^3/\text{s}$$

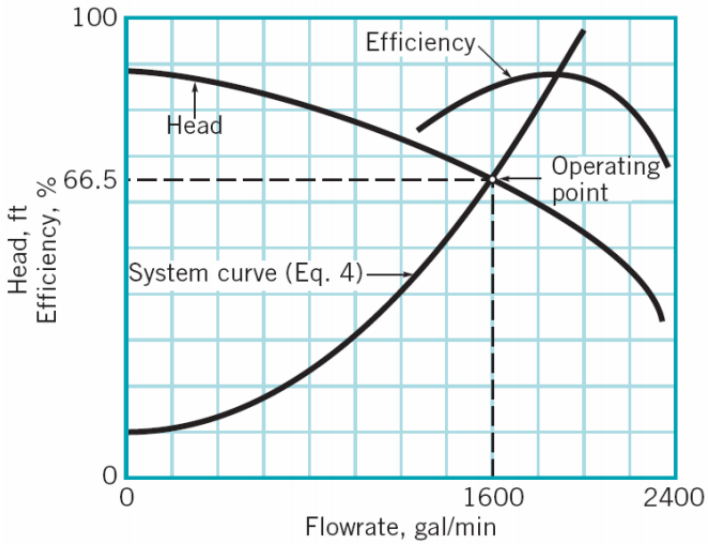
With Q in ft^3/s

$$h_p = 10 + 4.43Q^2 \quad \text{Eq. (3)}$$

With Q in gal/min

$$h_p = 10 + 2.20\times10^{-5}Q^2 \quad \text{Eq. (4)}$$

System equation for this particular flow system and reveals how much actual head the fluid will need to gain from the pump to maintain a certain flowrate.



Blower and compressor

❖ 일반적 정의

구 분	목 적	주이송, 상변화	정 의
펌 프 (Pump)	압 송	액체 또는 기체	압력의 작용에 의해 액체 또는 기체를 수송하는 장치
팬 (Fan)	압 송	기체	날개차의 회전운동에 의하여 기체를 압송하고 그 압력비가 1.1 또는 토출 압력 1000 mmAq 미만, 또는 공기 입출구 밀도비가 최대 7% 증가되는 기계
블로워 (Blower)	압 송	기체	팬(Fan) 보다 공기 입출구 밀도비(압력비)가 큰 송풍기계
압축기 (Compressor)	압 송	기체	날개차나 로터의 회전운동 또는 피스톤의 왕복운동에 의해 기체를 압축하고, 압축 후의 압력이 압축전의 기체의 압력의 2배 이상, 또는 압축 후의 토출력이 1 kg/㎠ 이상이 되는 기계

❖ 외형

펌프 (Pump)	팬(Fan)	블로워 (Blower)	압축기 (Compressor)
			

Blower and compressor

- As per American society of Mechanical Engineers (ASME)
  - ✓ the specific ratio-the ratio of discharge pressure over the suction

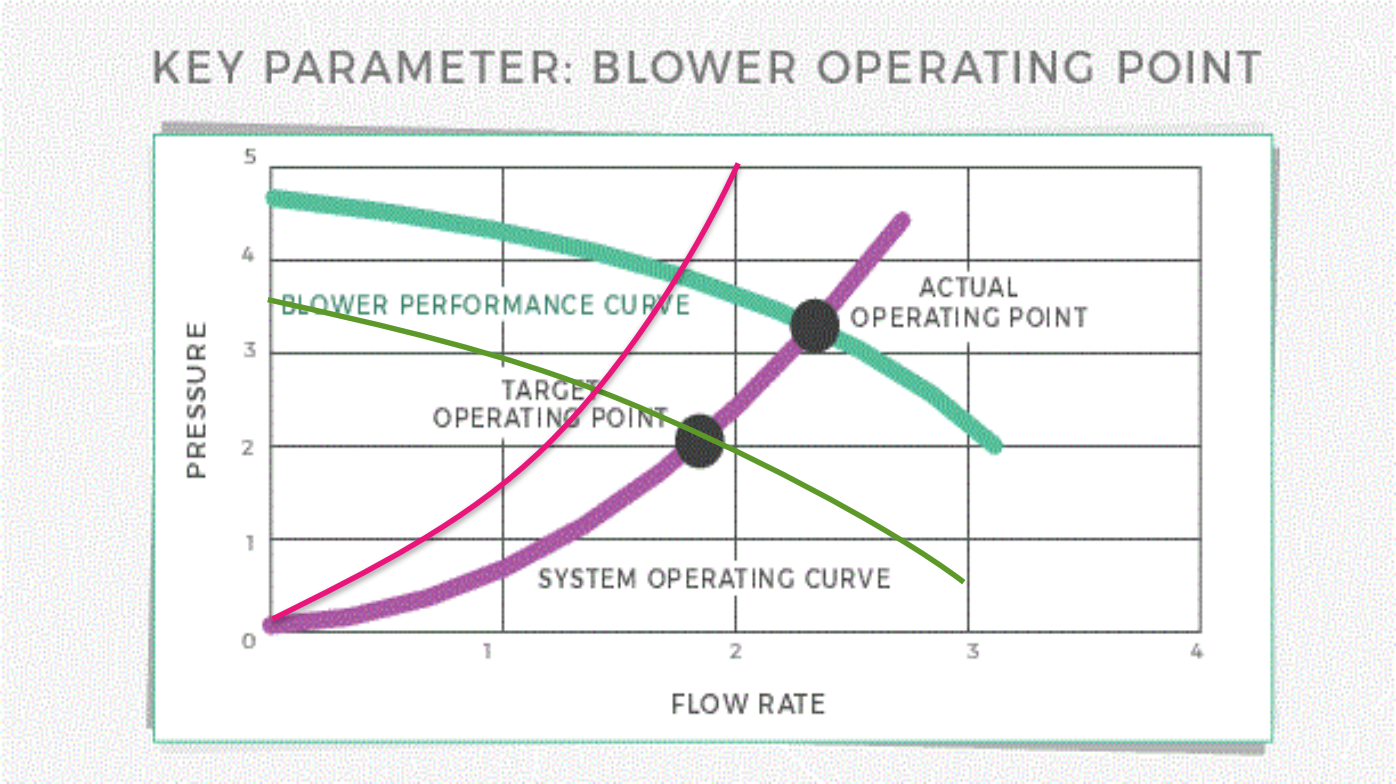
Equipment	Specific Ratio	Pressure rise (mmWg)
Fans	Up to 1.11	1136
Blowers	1.11 to 1.20	1136 – 2066
Compressors	more than 1.20	-

Fan과 Blower	• 일을 공급하여 기체의 압력을 약간 높임으로써 유동을 일으키는 장치 • 기체의 비체적은 큰 차이가 없음

- Fan과 Blower는 그 형상은 동일하나, 압력비(Rc)에 따라 Fan 또는 Blower로 구분되기 때문에 특별한 경우를 제외하고는 Fan으로 통일하여 부름
- 기체를 이송하는 기기의 분류 : Fan, Blower, Compressor

Blower and compressor

- Blower performance curve



Flow rate control

- Invertor control
  - ✓ 상용 전원으로부터 전력을 입력받아 자체 내에서 전압과 주파수를 가변시켜 모터에 공급함으로써 모터 속도를 제어하는 장치
  - ✓ 전압과 주파수를 가변시켜 모터의 속도를 제어하는 장치